PB-245 262

DIFFUSION-MODEL CALCULATIONS OF LONG-TERM AND SHORT-TERM GROUND-LEVEL SO2 CONCENTRATIONS IN ALLEGHENY COUNTY, PENNSYLVANIA

H. E. Cramer, et al

H. E. Cramer Company, Incorporated

Prepared for:

Environmental Protection Agency

March 1975

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U. S. DEPARTMENT OF COMMERCE

EPA 903/9-75-018

MARCH 1975

280072

PB 245 262

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Prepared By
H. E. Cramer, H. V. Geary and J. F. Bowers

Prepared For
U. S. ENVIRONMENTAL PROTECTION AGENCY
Region III
Philadelphia, Pennsylvania 19106

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SALT LAKE CITY, UTAH 84108

276

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA 903/9-75-018

2.

3. Recipient's Accession No.

4. Title and Subtitle

Diffusion Model Calculations of Long Term and Short Term Ground level SO_2 Concentrations in Allegheny County, PennaSYLVANiA

5. Report Date March 1975 DOC

6.

7. Author(s) H.E. Cramer, H.R. Geary, & J.F. Bowers

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

H.E. Cramer Company, Inc. - 540 Arapeen Drive,
University of Utah Research Park, Salt Lake City, Utah 84108

10. Project/Task/Work Unit No. Task Order #1

11. Contract/Grant No. Contract # 68-02-1387

12. Sponsoring Organization Name and Address

U.S. Environmental Protection Agency
Region III
Philadelphia, Pa. 19106

13. Type of Report & Period Covered Final

14.

15. Supplementary Notes

16. Abstracts

The report describes diffusion-model calculations of maximum 3-hour, 24-hour and average annual ground-level SO_2 concentrations in Allegheny County, Pa., produced by emissions from major stationary sources. Emissions data for 1973 and projected emissions data for a compliance case based on emissions-control regulations for attaining air quality standards were used. Standard Gaussian diffusion modeling techniques, including effects of terrain on plume height were used. Calculations of the vector wind fields along the Monongahela River, made by means of a numerical model based on a shallow fluid analogy, showed terrain features have a negligible effect on the wind field. Comparisons of the 1973 model calculations with observed air quality at the three continuous SO_2 monitoring sites for which data were available showed good agreement without any model calibration adjustments. Diffusion-model calculations for the compliance case emissions showed that the annual Primary Air Quality Standard will be exceeded in the Clairton-Glassport-Liberty Borough area and in an area of several square kilometers east of Braddock. Short-term diffusion-model calculations for the compliance case emissions showed that the 24-hour Primary Air Quality Standard will be exceeded in a small area in the vicinity of the Logans Ferry SO_2 monitor and, depending on the value assigned to the SO_2 background, may be exceeded in the Clairton-Liberty Borough area and in a small area east of Braddock. The short-term compliance case calculations also showed that the 3-hour Secondary Air Quality will not be exceeded.

17. Key Words and Document Analysis. 17a. Descriptors

17. Key Words and Document Analysis. 17a. Descriptors

Allegheny County, Penna.
Diffusion Model
Sulfur Dioxide Model

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement RELEASE UNLIMITED

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page UNCLASSIFIED

21. No. of Pages 271

22. Price 8.50-2.25

FORM NTIS-35 (REV. 3-72)

THIS FORM MAY BE REPRODUCED

USCOMM-DC 14952-P72

EPA 903/9-75-018

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ACKNOWLEDGMENT

Throughout the program of work culminating in the preparation of this report, the H. E. Cramer Company, Inc. has greatly benefited from the assistance, cooperation and guidance provided by many individuals.

We are especially indebted to our EPA Project Officer and EPA Region III Meteorologist, Dr. Peter Finkelstein, for his keen interest in all aspects of the work, for the excellence of his guidance and for the very efficient manner in which he assisted us in resolving many of the complexities of the work.

We are also very greatly indebted to the Director of the Allegheny County Bureau of Air Pollution Control, Mr. Ron J. Cheleboski, and to the professional staff of the Bureau who provided the bulk of the emissions and air quality data as well as much of the meteorological data used in the study. Expert assessment and interpretation of these data were provided by Mr. Bernard Bloom, Dr. Arvid Ek, Dr. Albert Smith, and Dr. Roger Westman of the engineering staff of the Allegheny County Bureau of Air Pollution Control.

In addition to the authors of the report, other professional staff members of the H. E. Cramer Company, Inc. who made important contributions to the work include Mr. J. R. Bjorklund, who was principally responsible for the computer programming and machine calculations, and Mr. L. D. Bodkin who performed most of the checking of the emissions and source data.

SUMMARY

This report describes diffusion-model calculations of maximum 3-hour, 24-hour and average annual ground-level SO_2 concentrations in Allegheny County produced by SO_2 emissions from 107 major stationary sources and source complexes located within or adjacent to the county boundaries. Two different sets of emissions data, both supplied by the Allegheny County Bureau of Air Pollution Control, were used in the diffusion-model calculations: emissions data for 1973 and projected emissions data for a compliance case based on emissions-control regulations for attaining and maintaining SO_2 air quality standards in Allegheny County. The 1973 emissions data were used with concurrent meteorological observations from the Greater Pittsburgh and Allegheny County Airports to calculate the 1973 average annual SO_2 ground-level maximums, as well as the 3-hour and 24-hour maximums for three selected 24-hour periods. These 1973 model concentrations were compared with observed air quality data from continuous monitoring sites supplied by the Allegheny County Bureau of Air Pollution Control to confirm the accuracy of the modeling techniques prior to performing the compliance case calculations. As an additional check on the diffusion-modeling techniques, a numerical mesoscale wind-field model was used to determine the effects of the elevated terrain along the Monongahela River on the trajectories of SO_2 plumes originating from the Clairton Coke Works during moderate to strong southwesterly flow. The results of the model calculations outlined above are summarized as follows:

Calculations of the vector wind fields along the Monongahela River, made by means of a numerical model based on a shallow fluid analogy, showed terrain features have a negligible effect on the trajectories of plumes from the Clairton Coke Works during periods of persistent west or southwest winds and moderate

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to strong temperature inversions. These conditions are typically associated with the highest observed 3-hour and 24-hour SO_2 concentrations at the Allegheny County monitors (Liberty Borough School and Glassport.).

Comparisons of the 1973 model calculations with observed air quality at the three continuous SO_2 monitoring sites for which data were available showed good agreement without any model calibration adjustments. According to the calculated average annual SO_2 ground-level concentrations for 1973, which do not include any SO_2 background estimates, the Annual Primary SO_2 Standard of 80 micrograms per cubic meter was exceeded in two large areas. The first of these covers approximately 120 square kilometers and extends along both sides of the Mononghela River from the southern boundary of Allegheny County north to the junction of the Monongahela with the Youghiogheny River. Emissions from the Elrama and Mitchell Power Plants and the Clairton Coke Works are principally responsible for the high SO_2 concentrations calculated for this area. The second large area in which the calculated average annual SO_2 ground-level concentrations for 1973 exceed the Annual Primary Standard covers approximately 40 square kilometers and is located principally on the north side of the Monongahela River, starting at a point directly opposite the Jones and Laughlin Pittsburgh Plant and extending upriver to a point opposite the U. S. Steel Homestead Plant. Emissions from these two plants are principally responsible for the high calculated SO_2 concentrations in this area.

The calculated 3-hour and 24-hour SO_2 ground-level maximums for three 1973 24-hour example cases showed that emissions from the West Penn Power Plant were almost entirely responsible for violations of the short-term SO_2 standards in a small area of approximately 1 square kilometer surrounding the Logans Ferry monitor. The 1973 short-term example calculations also showed that emissions from the Elrama and Mitchell Power Plants, the Irvin Works and the Clairton Coke Works, separately and in combination, caused violations of the 24-hour Primary Standard at various points on both sides of the Monongahela River. A very important and somewhat unexpected result of the 1973 short-term example calculations was the important contributions made at the Glassport and Liberty Borough monitors, as well as at other locations within Allegheny County, by the plumes from the Elrama and Mitchell Power Plants.

Diffusion-model calculations for the compliance case emissions showed that the annual Primary Air Quality Standard of 80 micrograms per cubic meter will be exceeded in the Clairton-Glassport-Liberty Borough area and in an area of several square kilometers east of Braddock. Emissions from the Clairton Coke Works are principally responsible for the calculated high annual average SO_2 concentrations in the Clairton-Glassport-Liberty Borough area while emissions from the Westinghouse Electric plant are principally responsible for the calculated high annual average SO_2 concentrations in the area east of Braddock. The compliance case concentration calculations also showed that the Annual Primary Standard will be equalled in the area surrounding the U. S. Steel Homestead plant. Short-term diffusion-model calculations for the compliance case emissions showed that the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter will be exceeded in a small area in the vicinity of the Logans Ferry SO_2 monitor and, depending on the value assigned to the SO_2 background, may be exceeded in the Clairton-Liberty Borough area and in a small area east of Braddock. The short-term compliance case calculations also showed that the 3-hour Secondary Air Quality Standard will not be exceeded.

The detailed results of all of the diffusion-model calculations made during the study are contained in twenty-five bound volumes consisting of 30,500 computer printout sheets which have been supplied to EPA. These volumes present complete listings of all source and meteorological inputs used in the calculations as well as the calculated concentrations at each grid point contributed independently by individual sources, source complexes and by all sources combined. The results of the calculations have also been recorded on magnetic tapes for possible future updating and revision.

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

Efficient management of air resources in the heavily industrialized area in Allegheny County, Pennsylvania requires a detailed knowledge of source-receptor relationships. As pointed out by Bloom and Smith (1974), most of the sulfur dioxide (SO_2) emissions within Allegheny County are accounted for by large stationary sources associated with coke, iron and steel production facilities and with coal-fired utility boilers. Seven large steel mills are located along the Monongahela River between downtown Pittsburgh and the southern extremity of Allegheny County. Additionally, there are six coal-fired electrical generating plants located either within or adjacent to Allegheny County. Observations of 3-hour and 24-hour SO_2 concentrations made at continuous SO_2 monitoring stations operated by Allegheny County show that the highest concentrations occur during periods of persistent south-southwest to west-southwest wind directions with moderate to high wind speeds. In many instances, strong low-level temperature inversions are also present but they do not appear to be requisite. Bloom and Smith (1974) note that all of the 3-hour SO_2 concentrations in excess of the Federal Secondary Standard recorded since 1971 by the continuous SO_2 monitoring network occurred during 24-hour periods in which the Federal Primary Standard was also exceeded. For this reason, we have principally concentrated our attention in this study on the 24-hour Primary Standard.

The complex fuel-usage system serving the U. S. Steel production facilities located along the Monongahela River makes it difficult to calculate accurate short-term SO_2 emission rates. The six production facilities operated by U. S. Steel (Clairton, Irvin, National, Duquesne, Edgar Thompson and Homestead) are all served by a common highly-integrated fuel system which contains a variable mixture of fuel oils, coal, natural gas, blast-furnaces gas, coke-oven gas and other coal derivatives. As pointed out by Bloom and Smith (1974), SO_2 emission rates from each of the several hundred exit points within these facilities vary widely depending on steel production rates, the availability of the various component fuels, and the availability of electrical generating equipment. We would also point out that there are significant short-term variations as well in the SO_2 emissions from the six electrical generating plants located within or immediately adjacent to Allegheny County.

The large land area covered by Allegheny County, the multiplicity of SO_2 sources, the high short-term variability of SO_2 emission rates, the very limited number of continuous SO_2 monitoring stations, and other factors effectively preclude the establishment by direct empirical methods of the relationships between SO_2 emissions and ambient air quality. The only practicable recourse currently available is to use atmospheric diffusion-modeling techniques capable of calculating, for multiple-source emissions, both short-term and long-term SO_2 ground-level concentrations at a very large number of grid points. The calculations must be performed in such a way that the contribution of each individual source as well as the contributions of combined sources can be identified at each grid point. Additionally, the models must be capable of adequately handling the effects of local terrain features and meteorological factors. Also, it is important that provisions be made to store the results of the multiple-source calculations on magnetic tape and to update calculations by repeated calculations involving only those sources for which the emissions or other source factors are altered. There are available for use in this study, as the result of recent work performed by the H. E. Cramer Company, Inc. for the State of Michigan and the U. S. Army, diffusion-modeling techniques and computer programs that very closely meet the above requirements.

This report describes the results obtained by the use of these newer techniques and computer programs to calculate SO_2 ground-level concentrations produced within Allegheny County for SO_2 emission control strategies specified by the Allegheny County Bureau of Air Pollution Control. It is not presumed that these calculations, or any diffusion-model calculations, can by themselves provide a definitive answer to the question of the emission control strategies best suited for attaining and maintaining SO_2 air quality standards. In addition to the judgment that must be used in evaluating the probable accuracy of such model calculations, there are clearly very important social and economic factors that must be considered. We believe, however, that diffusion-modeling techniques of the type described above offer the most promising method at hand for obtaining a comprehensive overview of the SO_2 problem in Allegheny County and the detailed definition of source-receptor relationships required to evaluate the effectiveness of SO_2 emission control strategies.

1.2 PURPOSE AND MAJOR TASKS

The principal purpose of the work described in this report is to make diffusion-model calculations of the 3-hour, 24-hour and annual average ground-level SO_2 concentrations in Allegheny County, using projected 1975 SO_2 emission rates for all major stationary sources supplied by the Allegheny County Bureau of Air Pollution Control. These projected 1975 emission rates reflect emissions regulations designed to attain and maintain both short-term and long-term ambient air quality standards. The results of the diffusion-model calculations will be used by EPA in evaluating the feasibility of achieving the requisite air quality standards for SO_2 in Allegheny County through the use of the Allegheny County emission regulations.

The program of work to be accomplished comprised the following six major tasks:

(1) Determination of the effects of prominent terrain features along the Monongahela River on the transport of airborne pollutants by using a computerized numerical model to calculate the vector wind-velocity fields above the area of interest and plume trajectories during periods of persistent southwesterly winds of moderate speed with near-neutral or slightly stable stratification.

(2) Development of the meteorological, terrain and source inputs required for model calculations of the average annual, 3-hour and 24-hour SO_2 ground-level concentrations within Allegheny County.

(3) Preparation and adaptation of computer programs and diffusion models.

(4) Model calculations of 1973 annual average concentrations as well as 3-hour and 24-hour concentrations for three selected 24-hour periods during 1973 when high SO_2 concentrations were observed at air quality monitoring sites.

(5) Comparison of 1973 model calculations with 1973 air quality data to test the accuracy of the modeling techniques.

(6) Use of projected 1975 emissions data with worst-case meteorological inputs to calculate maximum long-term and short-term SO_2 ground-level concentrations.

1.3 REPORT CONTENT AND ORGANIZATION

The effects of terrain on low-level wind fields in the Clairton Liberty-Borough area, as revealed by vector wind-field calculations made by means of a computerized numerical model, are described in Section 2. Meteorological data as well as the meteorological inputs used in the long-term and short-term concentration calculations are described in Section 3. The calculation procedures used and the results obtained for the 1973 average annual concentrations, as well as comparisons between calculated and observed values, are given in Section 4. The annual average concentration calculations for the projected SO_2 emissions (compliance case) are described in Section 5. Short-term concentration calculations for three 24-hour air pollution episodes during 1973 are presented in Section 6, while the calculated maximum 3-hour and 24-hour concentrations for the compliance case are given in Section 7. The results of all the long-term and short-term model calculations are summarized in Section 8.

Additional information is presented in three appendices. Appendix A contains a complete description of the diffusion-modeling techniques used in the study including the mathematical formulas. Appendix B contains tabular summaries of the seasonal and annual joint frequency distributions of wind speeds and wind directions, classified by Pasquill stability category, for the years 1973 and 1965 which were developed from hourly and 3-hourly surface observations made at the Greater Pittsburgh and Allegheny County Airports. Appendix C describes the contents of the short-term and long-term computer programs used to make all the concentration calculations for the study and explains the data formats for the computer printout sheets supplied to EPA. This printout, which comprises 30,500 pages contained in twenty-five separately bound volumes, provides a complete listing of all input parameters used in the calculations as well as the concentrations calculated at each grid point for each source, source group and all sources combined.

SECTION 2

EFFECTS OF TERRAIN ON LOW-LEVEL WIND CIRCULATION PATTERNS IN THE CLAIRTON AREA

2.1 BACKGROUND

In the atmospheric dispersion model currently available for general application to urban air pollution problems it is usually assumed, for simplicity, that the low-level wind field is uniform over the entire area and is unaffected by local variations in terrain features that may occur at various points within the area. A question arises as to the validity of the uniform wind-field assumption along the Monongahela River Valley in the area of the Clairton Coke Works where the differences in elevation between the valley floor and the ridge line vary from about 85 to 150 meters (300 to 500 feet). Specifically, we wish to know whether there is an objective basis for postulating that terrain features along the Monongahela River cause significant local variations in the mean wind flow such that SO_2 emissions from the Clairton Coke Works follow curvilinear trajectories. Detailed wind observations of the type required to provide a direct answer to this question are not available and are logistically impossible to obtain. The most objective alternative approach currently available is to use a computerized numerical model (Tingle and Bjorklund, 1973) capable of calculating the effects of terrain obstacles on the low-level wind field during periods of persistent moderate to strong winds and in the presence of an elevated temperature inversion that restricts the vertical growth of plumes. These meteorological conditions are identified with high ground-level SO_2 concentrations observed at the Liberty Borough and Glassport monitoring stations operated by the Allegheny County Bureau of Air Pollution Control. This section of the report briefly describes the numerical modeling techniques and summarizes the results obtained from model calculations of the low-level wind fields in the area surrounding the Clairton Coke Works under the meteorological conditions outlined above.

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2.2 THE NUMERICAL WIND FIELD MODEL

Tingle and Bjorklund (1973) have developed and tested a two-layer numerical model for calculating wind fields above complex terrain that is based on the shallow-water equations of oceanography. In this model the atmosphere above the complex terrain is divided into two layers of different density: a lower active layer, capped by a temperature inversion, above which there is a deep passive layer of lesser density. The passive layer acts to reduce the speed of gravity waves in the lower layer and the height of the temperature inversion, which coincides with the top of the lower layer, is analogous to the free water surface of a single-layer shallow-water model with a reduced acceleration of gravity. The wind patterns are obtained by impulsively accelerating the velocity in the lower layer to a preselected value and by using the computerized shallow-fluid model to calculate the velocity field at fixed, sequential time steps until an approximate steady state is achieved. Basic features of the two-layer shallow fluid model are shown schematically in Figure 2-1. The symbols in the figure are defined as follows:

p_o = density of the lower action layer

p_1 = density of the upper passive layer ($p_o > p_1$)

ϕ = height of the temperature inversion surface capping the lower layer

H = terrain elevation

g = gravitational constant

u = wind velocity in the active layer

We believe the shallow-fluid model developed by Tingle and Bjorklund (1973) is well suited for application to an evaluation of the effects of terrain in the Clairton

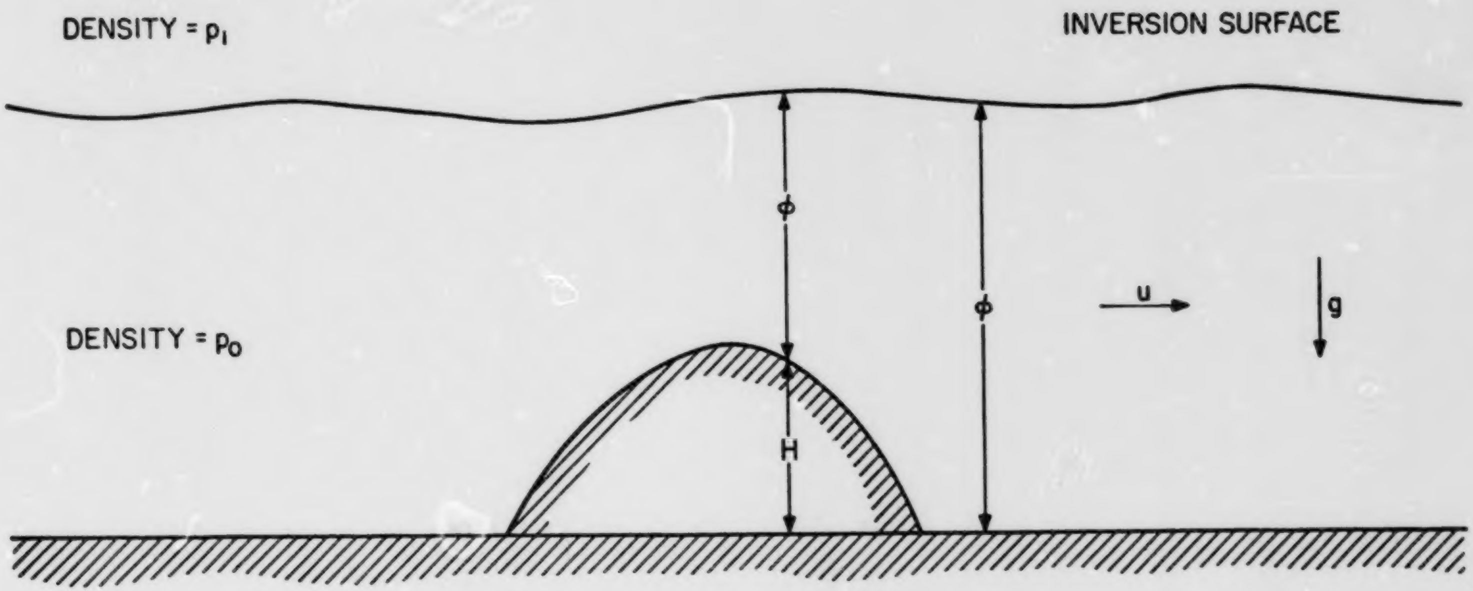

DENSITY = ρ_1
INVERSION SURFACE
ϕ
ϕ
u
g
DENSITY = ρ_0
H

FIGURE 2-1. Illustration of two-layer shallow-fluid model.

area on wind circulation patterns because the meteorological conditions of interest are precisely those for which the model was developed: a layer of persistent moderate to strong wind speeds, capped by a temperature inversion under neutral or slightly stable stratification, with the terrain influence dominating.

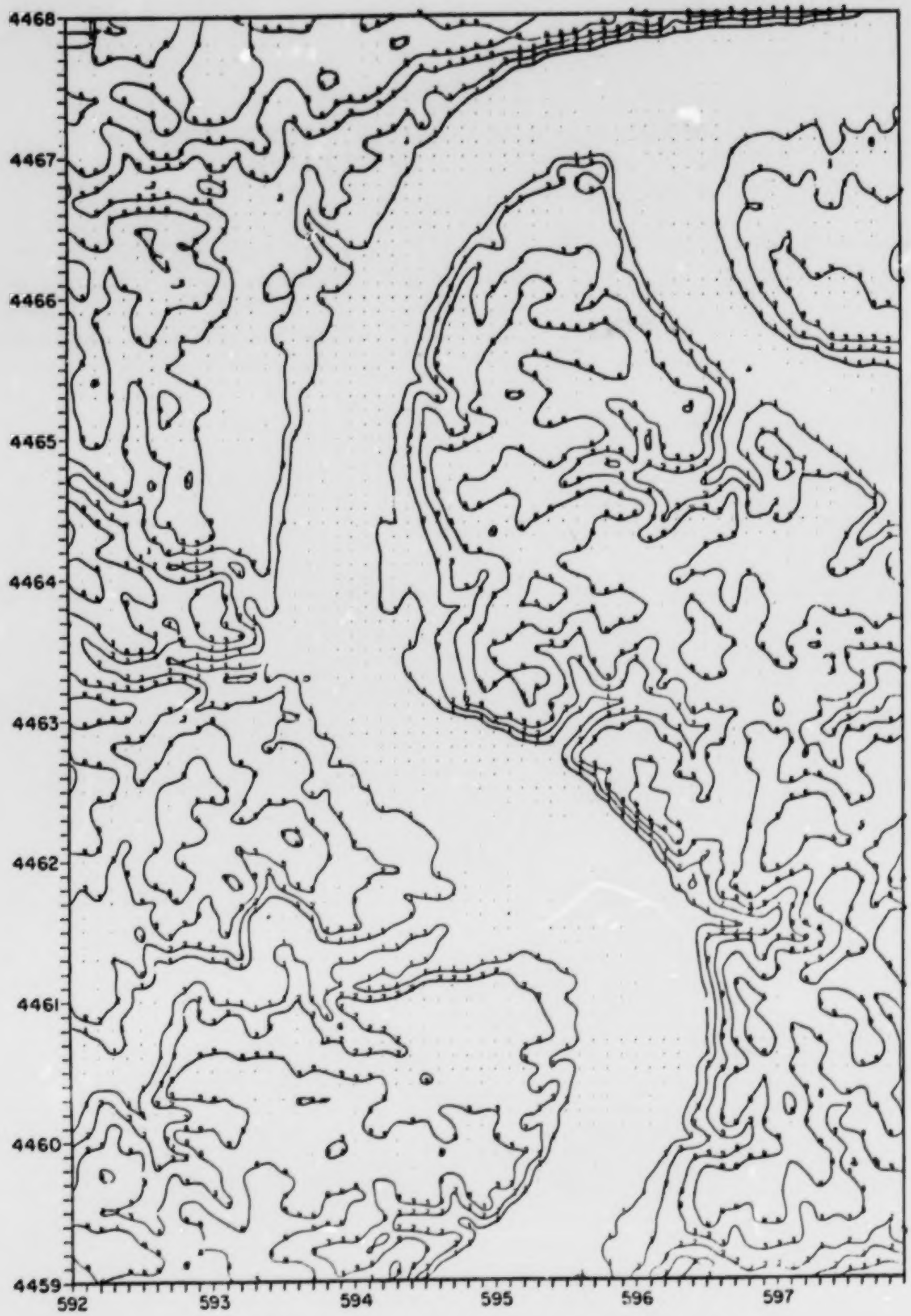
2.3 CALCULATION PROCEDURES AND RESULTS

Terrain elevations in the Clairton area were abstracted from topographic maps at regular 100-meter intervals in the horizontal plane and digitized for input to the wind-field computer model. Figure 2-2 shows a contour map of the computational grid that was automatically plotted using the digitized terrain data; the vertical contour interval in Figure 2-2 is 30 meters. The Monongahela River appears in the center of the grid. The maximum terrain height is approximately 390 meters above the mean sea level.

In addition to the terrain heights, the computer model requires as inputs the mean wind direction and speed, the height of the inversion level and the density difference across the inversion. In the Clairton area southeast of Pittsburgh, it is desired to know whether emissions from sources along the west bank of the Monongahela River are transported in an approximate straight line across the river when the wind is from the southwest or west-southwest, or whether the emissions are channeled by the river valley north toward the Glassport area.

Table 2-1 summarizes the meteorological input parameters used in three computer runs of the shallow fluid model, which we believe to be an adequate number of runs on the basis of previous experience with the shallow fluid models. West-southwest and southwest winds were used for the mean wind directions in the surface mixing layer while the mean wind speeds in the mixing layer were set equal to 8 and 8.75 meters per second.

An analysis of mixing depth data for the Greater Pittsburgh Airport (see Section 3) indicates that, for a mean wind speed of 8 meters per second, the top of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597

FIGURE 2-2. Topographic map of the southeast Pittsburgh calculation grid. The contour labeled 1 corresponds to a height of 244 meters above mean sea level, and the contour interval is 30 meters. The x and y axes are labeled with the Universal Transverse Mercator coordinates in kilometers.

TABLE 2-1

METEOROLOGICAL INPUTS FOR THE PITTSBURGH WIND-FIELD CALCULATIONS

Run	Mixing Depth (m above MSL)	Mean Layer Wind Speed (m/sec)	Mean Layer Wind Direction (deg)	Density Difference Across Inversion (%)
1	960	8	247.5	1
2	680	8.75	222.5	2
3	410	8	247.5	2

the mixing layer is generally greater than 960 meters above mean sea level (about 590 meters above the airport). This value was used for the mixing depth in Computer Run 1 with a change in density across the inversion of 1 percent. This corresponds to a temperature difference across the inversion of 2.5 degrees Celsius. When these input values were used in the model, the calculated steady-state wind field showed no significant changes due to terrain effects.

In Computer Run 2, the density difference was increased to 2 percent, the mixing depth was reduced to 680 meters and the mean wind speed was increased to 8.75 meters per second in an effort to force the terrain effect. Figure 2-3 shows a vector plot of the adjusted winds for Computer Run 2 and the trajectories of parcels originating at three points on the west bank of the Monongahela River. The trajectory at the top of the figure originates at the U. S. Steel Irvin plant and the trajectories at the bottom of the figure originate at the northern and southern boundaries of the Clairton Coke Works. The orientation of each vector shows the direction of the wind at the grid point and the length of each vector is proportional to the mean wind speed in the layer. For convenience, the trajectories in Figure 2-3 have been reproduced on a base map of the Clairton-Liberty Borough area in Figure 2-4. As shown by Figure 2-3, the major terrain effects on the wind field are changes in wind velocity rather than in wind direction. The trajectories show a maximum lateral deviation from a straight-line trajectory of about 300 meters.

If the base of the inversion layer is located just above the river channel, air trajectories are of course forced to follow along the channel. Computer Run 3 was made to show that the model reproduces these effects. The mixing depth for this calculation was set just 20 meters above the highest terrain elevation. The Run 3 vector plot for the Clairton portion of the calculation grid is shown in Figure 2-5. The trajectories in Figure 2-5 are also shown on a base map in Figure 2-6. All five trajectories in Figures 2-5 and 2-6 originate at the Clairton Coke Works. As shown by Figure 2-5, the calculated wind field was significantly affected by the terrain in this case. To the southwest (near Elizabeth), the wind follows the valley.

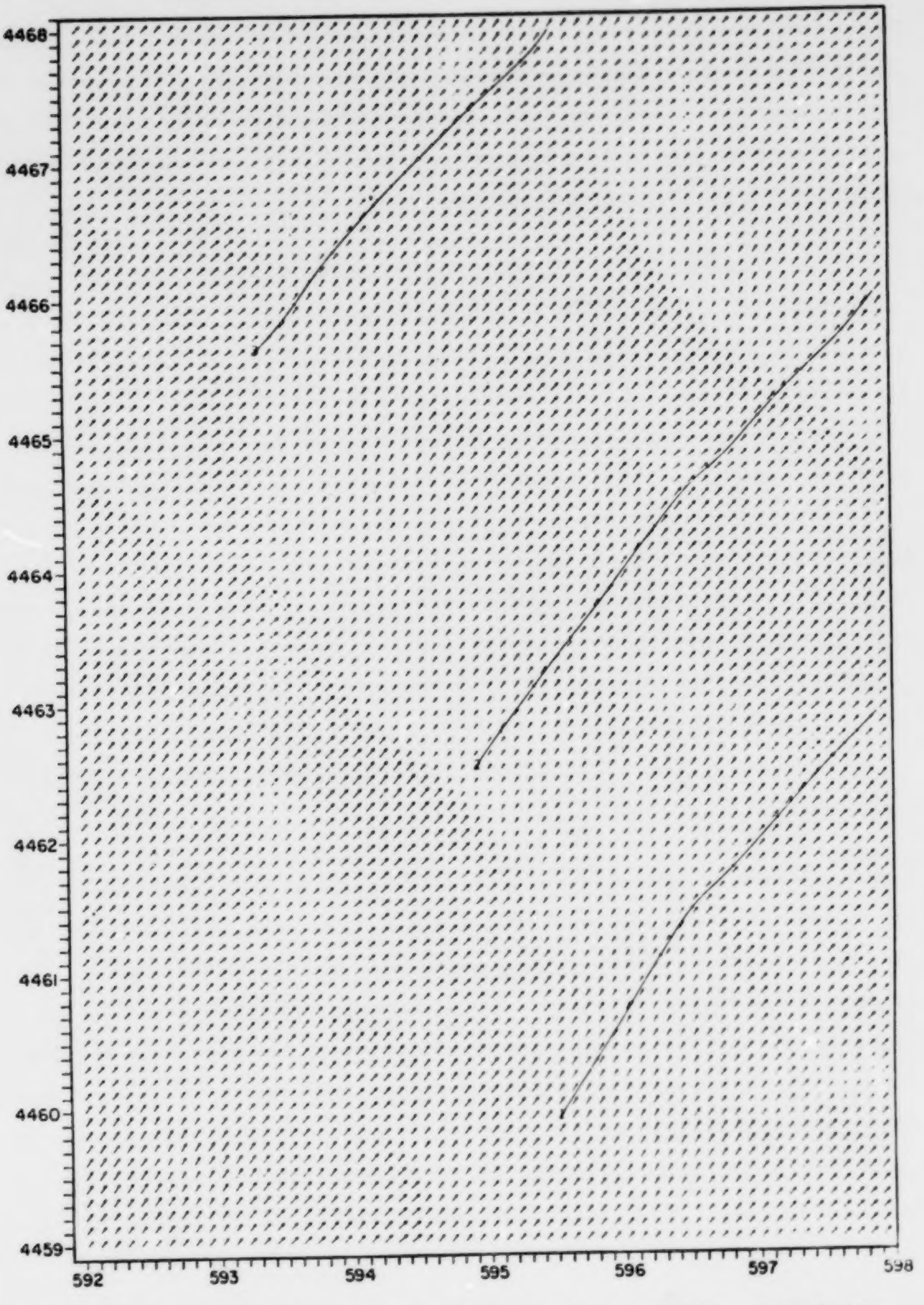

FIGURE 2-3. Vector plot of the calculated wind field and three example trajectories for Computer Run 2. The x and y axes are labeled with the Universal Transverse Mercator coordinates in kilometers.

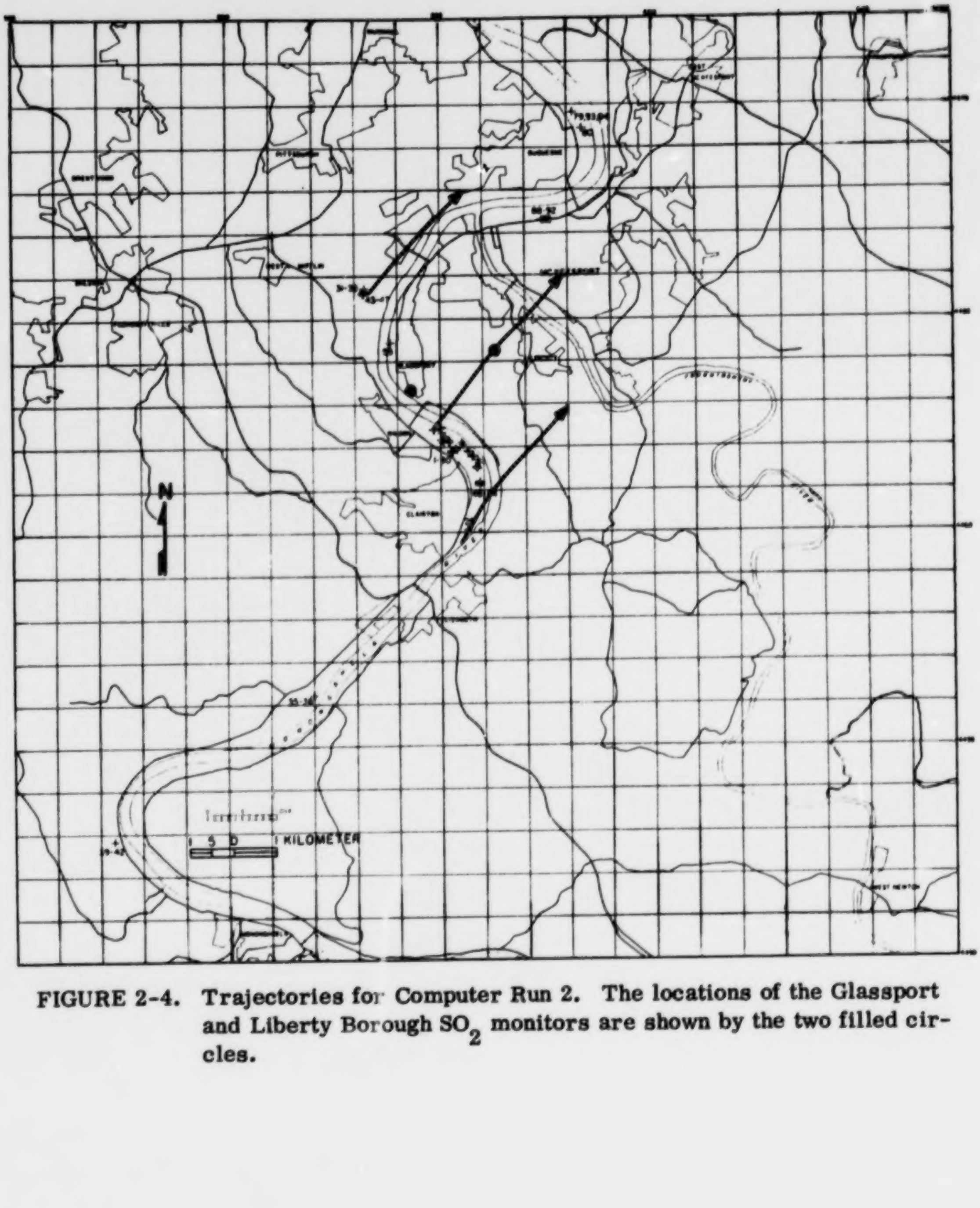
N
1 .5 0 1 KILOMETER
McKEESPORT
CLAIRTON

FIGURE 2-4. Trajectories for Computer Run 2. The locations of the Glassport and Liberty Borough SO_2 monitors are shown by the two filled circles.

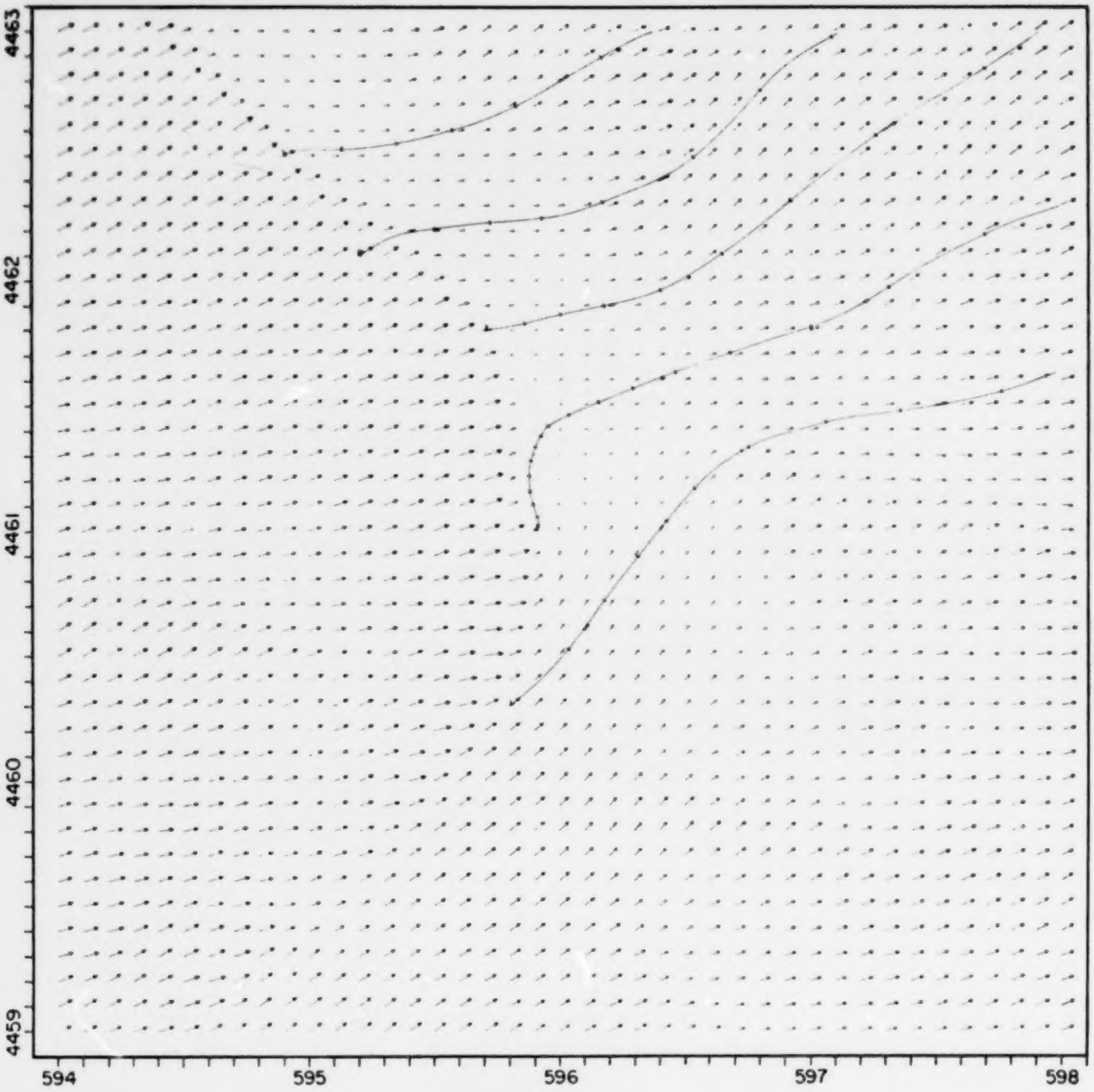

FIGURE 2-5. Vector plot of the calculated wind field and example trajectories for Computer Run 3. Note that only a portion of the calculation grid shown in Figure 2-2 is included in this figure.

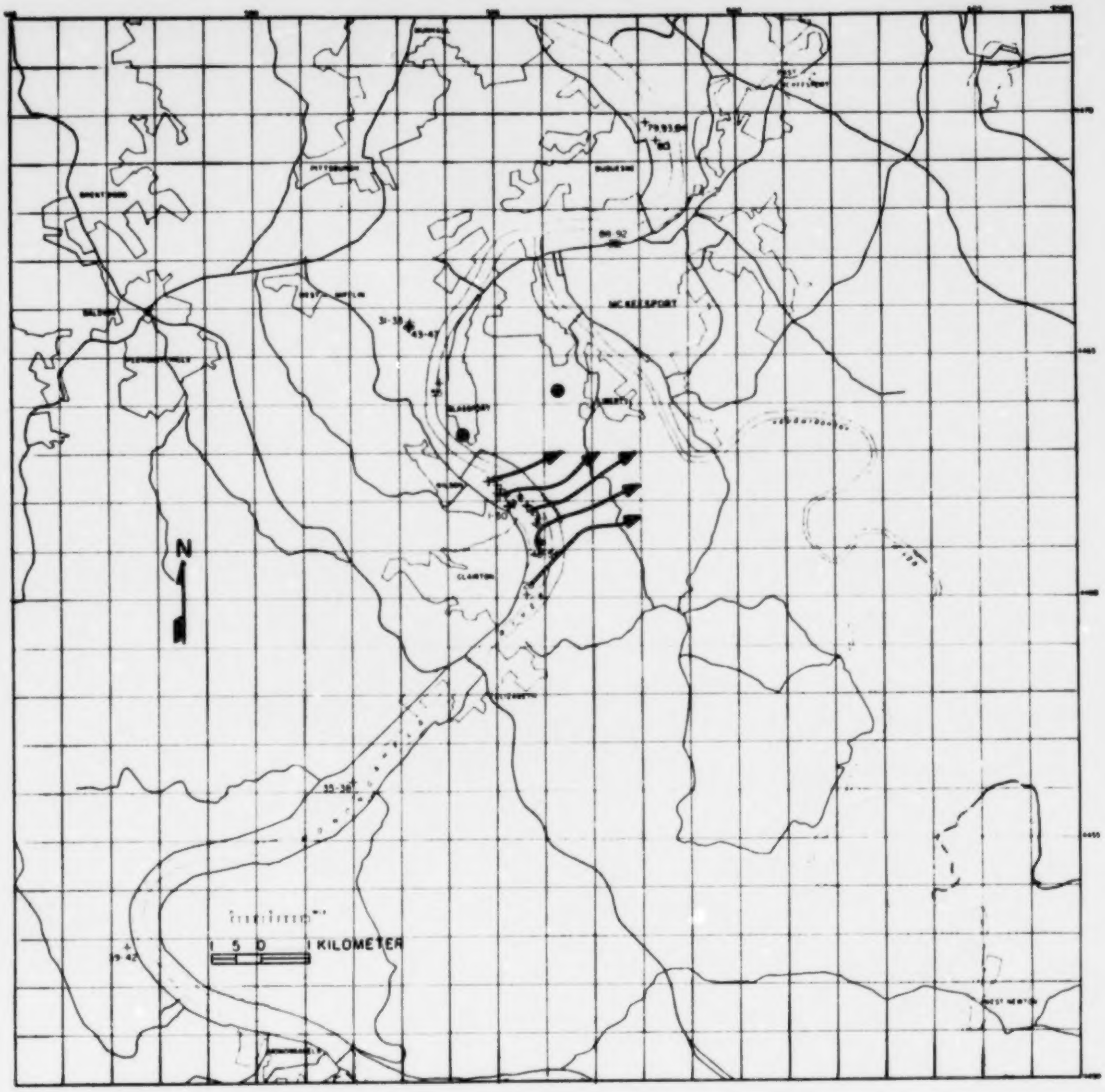
BRENTWOOD
PITTSBURGH
DUQUESNE
79,93,94
80
86-92
WEST MIFFLIN
31-38
43-47
MC KEESPORT
GLASSPORT
LIBERTY
1-10
CLAIRTON
N
35-38
39-42
1 .5 0
1 KILOMETER
WEST NEWTON

FIGURE 2-6. Trajectories for Computer Run 3. The locations of the Glassport and Liberty Borough SO_2 monitors are shown by the two filled circles.

Near Clairton, the winds are light and southerly, but gradually turn east and head toward the Lincoln School. From Clairton to Glassport, the river channel has only a minor influence on the winds, but at Glassport the winds again become southerly and follow the valley. Except for the area to the west of Clairton near the intersection of Peters Creek and Highway 51, the wind field is only slightly altered by the terrain even in this extreme case.

2.4 CONCLUSIONS

Calculations using the "shallow water" equations indicate that the Monongahela River channel and adjacent valleys and hillsides have a negligible effect on the mean wind field in the surface mixing layer except with an extremely low and intense temperature inversion in combination with strong southwesterly winds. We believe this combination is very unlikely and the occurrence of very low mixing depths with strong winds is not supported by the Greater Pittsburgh Airport mixing depth data. We therefore conclude that the effects of terrain on the wind circulation in the surface mixing layer, in the presence of moderate to strong winds, are slight. It is recognized that the surface winds in the river valleys do tend to follow the terrain and, therefore, some pollutants (expecially low-level fugitive emissions) will be transported by the valley wind circulation. However, because the mixing layer extends well above the highest terrain and because the stabilization heights of the buoyant stack emissions from the Clairton Coke Works are generally also above the highest terrain, the bulk of the SO_2 emissions are unaffected by the surface winds in the river valley.

SECTION 3

METEOROLOGICAL DATA

3.1 INTRODUCTION

The meteorological input parameters used to calculate long-term and short-term ground-level concentration patterns are defined in Appendix A in conjunction with detailed descriptions of the model equations. For both the long- and short-term model calculations, specific values of the meteorological input parameters are assigned on the basis of the Pasquill stability categories using the method suggested by Turner (1964) for relating hourly surface observations of cloud cover and mean wind speed to the various stability categories.

In the long-term model calculations for the year 1973, the assignment of Pasquill stability categories was made by using 1973 hourly surface wind observations from the Allegheny County Airport in combination with concurrent 3-hourly cloud-cover observations at the Greater Pittsburgh Airport (hourly observations at Allegheny County Airport of cloud cover and other meteorological parameters were not available for 1973). This procedure of combining the surface observations from the two airports was adopted because, in our judgment, the surface wind observations from the Allegheny County Airport are more likely to be representative of the wind circulation in the Clairton-Liberty Borough area, which is of prime interest due to the excessively high SO_2 concentrations.

In the long-term compliance calculations (see Section 5.1), Pasquill stability categories were assigned by using the hourly surface observations from the Greater Pittsburgh Airport for the year 1965. This particular year was chosen for the compliance calculations on the basis of an earlier diffusion-model study by Rubin (1974) who concluded that 1965 represented the poorest annual dilution conditions in the Pittsburgh area during the seven-year period from 1965 through 1971.

In the short-term model calculations for 1973, concurrent hourly surface wind measurements from the Allegheny County Airport and the Greater Pittsburgh Airport were averaged to obtain hourly surface wind inputs for the three 24-hour periods studied: the 18 January 1973 and 13 July 1973 episodes in the Clairton-Liberty Borough area and the 4 January 1973 episode at Logans Ferry. Pasquill stability categories were determined from the average hourly surface wind speeds mentioned above and hourly cloud cover observations from the Greater Pittsburgh Airport.

A general discussion of the procedures used to assign Pasquill stability categories and to develop the requisite meteorological inputs for the long- and short-term model calculations is presented below. Specific parameter values and other details are found in Sections 4 through 7 which describe the model calculations for each example 1973 case and each compliance case.

3.2 DEFINITIONS OF THE PASQUILL STABILITY CATEGORIES

The procedures developed by Turner (1964) for determining the Pasquill stability category from hourly airport surface weather observations are summarized in Tables 3-1 and 3-2 which list the wind-speed classes and the parameter values of the solar radiation (insolation) index assigned to the various stability categories. The wind speeds in Table 3-1 are in knots because airport surface wind speeds are reported to the nearest knot by the National Weather Service and Turner's classification is based on this convention. The thermal stratifications represented by the various Pasquill stability categories are:

- A - Extremely unstable
- B - Unstable
- C - Slightly unstable
- D - Neutral

TABLE 3-1

PASQUILL STABILITY CATEGORY AS A FUNCTION OF INSOLATION AND WIND SPEED

Wind Speed (knots)	Insolation Index						
	4	3	2	1	0	-1	-2
0, 1	A	A	B	C	D	F	F
2, 3	A	B	B	C	D	F	F
4, 5	A	B	C	D	D	E	F
6	B	B	C	D	D	E	F
7	B	B	C	D	D	D	E
8, 9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
≥12	C	D	D	D	D	D	D

TABLE 3-2

INSOLATION CATEGORIES

Insolation Category	Insolation Index
Strong	4
Moderate	3
Slight	2
Weak	1
Overcast < 7000 feet (day or night)	0
Cloud Cover > 4/10 (night)	-1
Cloud Cover ≤ 4/10 (night)	-2

- E - Slightly stable
- F - Stable

In both the long- and short-term calculations, the E and F categories have been combined because we believe that the effects of surface roughness and heat sources in the Pittsburgh area are incompatible with the small diffusion coefficients and minimal turbulent mixing associated with the Pasquill stability category F. Calder (1971) also recommends that the Pasquill stability categories E and F be combined for diffusion-model calculations in urban areas.

3.3 GENERAL METEOROLOGICAL INPUTS

The following procedures were used to specify the general meteorological inputs required by the long- and short-term diffusion models described in Appendix A.

Wind-Profile Exponents

In the diffusion models, the variation with height of the wind speed in the surface mixing layer is assumed to follow a wind-profile exponent law of the form

$$\bar{u}\{z\} = \bar{u}\{z_R\}\left(\frac{z}{z_R}\right)^p \tag{3-1}$$

where

$\bar{u}\{z\}$ = wind speed at height z above the surface

$\bar{u}\{z_R\}$ = wind speed at a reference height z_R above the surface

p = the wind-profile exponent

In the case of discharges from tall stacks, as discussed in Sections A. 3 and A. 5 of Appendix A, the wind-profile exponent law is used to adjust the mean wind speed from the reference (airport-measurement) height to the stack height for the plume rise calculations, and to the plume stabilization height for the concentration calculations. In the case of low-level emissions, which are generally treated as building sources, the wind-profile exponent law is similarly used to obtain the wind speed at the assigned source height which depends on the vertical dimensions of the buildings or other structures. Values for the wind-profile exponent p assigned to the various combinations of wind speed and stability for the long-term calculations are listed in Table 3-3. These exponent values are based on the results obtained by De Marrais (1959) and Cramer, et al. (1972).

For the three 1973 short-term calculations, values for the wind-profile exponent p were estimated from vertical wind profiles measured at the Greater Pittsburgh Airport by the following procedure. For specified values of $\bar{u}\{z_R\}$ and z_R, Equation (3-1) reduces to the form

$$\bar{u}\{z\} = a\, z^p \qquad (3\text{-}2)$$

where

$$a = \bar{u}\,\{z_R\}\, z_R^{\ -p}$$

Wind-speed measurements at standard heights from the twice-daily Greater Pittsburgh Airport rawinsonde releases were averaged for each 24-hour period of interest to obtain a vertical profile of average wind speeds in the surface mixing layer. The average wind speeds were fitted to a logarithmic least-squares curve using the regression technique recommended by Brownlee (1965) for fitting data points to a power-law curve of the type contained in Equation (3-2). In applying Brownlee's technique, Equation (3-2) is first written in logarithmic form as

TABLE 3-3

WIND-PROFILE EXPONENTS USED IN THE ANNUAL AVERAGE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind-Speed Category (m/sec)*					
	0-1.5	1.6-3.1	3.2-5.1	5.2-8.2	8.3-10.8	>10.8
A	0.10	0.10	-	-	-	-
B	0.10	0.10	0.10	-	-	-
C	0.20	0.15	0.10	0.10	0.10	-
D	0.25	0.20	0.15	0.10	0.10	0.10
E	0.30	0.25	0.20	-	-	-

*Measurement height is 6.1 meters above the ground surface.

$$\ln \bar{u}\,\{z\} = p \ln z + \ln a \tag{3-3}$$

The expression for the wind-profile exponent p is then given by

$$p = \frac{N \sum_{i=1}^{N} (\ln z_i \ln \bar{u}_i) - (\sum_{i=1}^{N} \ln z_i)\ (\sum_{i=1}^{N} \ln \bar{u}_i)}{N \sum_{i=1}^{N} (\ln z_i)^2 - (\sum_{i=1}^{N} \ln z_i)^2} \tag{3-4}$$

where the summations are over the N values of z and ū.

Similarly, the coefficient a is defined by

$$\ln a = \frac{\sum \ln \bar{u}}{N} - \frac{\sum \ln z}{N}\, p \tag{3-5}$$

and the correlation coefficient r is given by

$$r = \frac{N \sum (\ln z\ \mathrm{lu}\ \bar{u}) - (\sum \ln z)(\sum \ln \bar{u})}{\sqrt{\left[N \sum (\ln z)^2 - (\sum \ln z)^2\right] \left[N \sum (\mathrm{lu}\ \bar{u})^2 - (\sum \ln \bar{u})^2\right]}} \tag{3-6}$$

To illustrate our use of the above regression technique, we will describe the calculation of the wind-profile exponent p used in the diffusion-model calculations for the 4 January 1973 air pollution episode at Logans Ferry (see Section 6.1). Table 3-4 lists the wind speeds obtained from rawinsonde soundings made at the Greater Pittsburgh Airport at 1900 EST on 3 January, 0700 and 1900 EST on 4 January, and 0700 EST on 5 January. The wind speeds in the table have been converted from knots (the units used by the National Weather Service) to meters per second. The mean wind profile, obtained by averaging the winds from the four soundings, was used with Equations (3-4) through (3-6) to calculate the following parameter values:

$p = 0.17$

$a = 5.06$

$r = 0.98$

TABLE 3-4

VERTICAL PROFILES OF WIND SPEED MEASURED AT THE GREATER PITTSBURGH AIRPORT DURING THE PERIOD 3 THROUGH 5 JANUARY 1973

Height (m above ground level)	Wind Speed (m/sec)				
	3 January 1900 EST	4 January 0700 EST	4 January 1900 EST	5 January 0700 EST	Mean
6 (surface)	6.2	10.3	6.2	6.2	7.2
259	13.4	14.4	11.3	7.2	11.6
564	19.6	19.6	13.4	9.3	15.4
869	24.7	23.2	12.9	6.2	16.7
1478	21.1	27.3	17.5	11.8	19.4

The calculated value of 0.17 for the wind-profile exponent p was used in the short-term concentration calculations for the 4 January 1973 air pollution episode at Logans Ferry. Values of the wind-profile exponent p used in the other 1973 short-term calculations and in the short-term compliance case calculations are given in Sections 6 and 7, respectively.

Vertical Turbulent Intensities

Our vertical expansion (σ_z) curves, which include the effects of the initial vertical plume or building dimension, relate the vertical turbulent intensity directly to plume growth (see Equation (13) of Appendix A). Table 3-5 lists the values of the standard deviation of the wind elevation angle σ'_E corresponding to the Pasquill stability categories for rural and urban areas. The rural σ'_E values are based in part on the measurements of Luna and Church (1971) and are consistent with the σ'_E values implicit in the σ_z curves presented by Pasquill (1961). In order to adjust for the effects of surface roughness elements and heat sources, the σ'_E values for the stability category one step more unstable than the indicated stability category are used in the calculations for urban areas. A procedure of this type is suggested by Calder (1971), Bowne (1974) and others and is consistent with the combining of Pasquill stability categories E and F in urban areas noted in Section 3.2.

Lateral Turbulent Intensities

Our lateral expansion (σ_y) curves, which also include the effects of the initial lateral plume or building dimension, relate the lateral turbulent intensity directly to plume growth (see Equation (11) of Appendix A). In our calculations, we assumed that the standard deviation of the wind azimuth angle σ'_A is equivalent to σ'_E for a 10-minute averaging period. The $t^{1/5}$ law suggested by Osipov (1972) and others was then used to obtain hourly σ'_A values. That is, σ'_E for a given stability category was multiplied by 1.43 ($6^{1/5}$) to obtain the corresponding hourly σ'_A value. Table 3-5 also lists the σ'_A values for rural and urban areas.

TABLE 3-5

TURBULENT INTENSITIES FOR RURAL AND URBAN AREAS

Pasquill Stability Category	σ'_E (radians)		σ'_A (radians)	
	Rural	Urban	Rural	Urban
A	0.1745	0.1745	0.2495	0.2495
B	0.1080	0.1745	0.1544	0.2495
C	0.0735	0.1080	0.1051	0.1544
D	0.0465	0.0735	0.0665	0.1051
E	0.0350	0.0465	0.0501	0.0665
F	0.0235	--	0.0336	--

Mixing Depths

The height of the top of the surface mixing layer is defined as the height at which the vertical intensity of turbulence becomes effectively zero. This condition is fulfilled when the vertical turbulent intensity is of the order of 0.01 or smaller. Since direct measurements of the intensity of turbulence are not routinely made, indirect indicators such as discontinuities in the vertical wind and temperature profiles must be used to estimate the depth of the surface mixing layer. In the simplest case, the base of an elevated inversion layer is usually assumed to represent the top of the surface mixing layer. However, even with a surface-based inversion, a shallow mixing layer will exist due to the presence of surface roughness elements and, in urban areas, surface heat sources.

Holzworth (1972) has developed a procedure for estimating early morning and afternoon mixing depths for urban areas from rawinsonde observations and surface temperature measurements. Tabulations of daily observations of the depth of the surface mixing layer, developed by using the Holzworth (1972) procedures, are available for most rawinsonde stations operated by the National Weather Service. For the seasonal concentration calculations, we analyzed seasonal tabulations of daily observations of mixing depth and average surface wind speed at the Greater Pittsburgh Airport for the period 1960 through 1964 (Environmental Data Service, 1966) in order to determine seasonal median early morning and afternoon mixing depths for each wind-speed category. The median afternoon mixing depths were assigned to the A, B and C stability categories; the median early-morning mixing depths were assigned to the combined E and F stability categories; and the median early morning and afternoon mixing depths were averaged and assigned to the D stability category. Table 3-6 gives the seasonal median mixing depths for the joint combinations of the wind-speed and stability categories determined for the Pittsburgh area.

TABLE 3-6

MIXING-LAYER DEPTHS IN METERS USED IN THE ANNUAL CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind-Speed Category (m/sec)					
	0-1.5	1.6-3.1	3.2-5.1	5.2-8.2	8.3-10.8	>10.8
(a) Winter						
A	500	650	--	--	--	--
B	500	650	710	--	--	--
C	500	650	710	710	710	--
D	320	470	670	710	710	710
E	140	290	630	--	--	--
(b) Spring						
A	1530	1530	--	--	--	--
B	1530	1530	1530	--	--	--
C	1530	1530	1530	1530	1530	--
D	825	920	1030	1415	1530	1530
E	120	310	530	--	--	--
(c) Summer						
A	1730	1730	--	--	--	--
B	1730	1730	1730	--	--	--
C	1730	1730	1730	1730	1730	--
D	960	1025	1235	1295	1295	1295
E	190	320	740	--	--	--
(d) Fall						
A	1230	1230	--	--	--	--
B	1230	1230	1230	--	--	--
C	1230	1230	1230	1230	1230	--
D	685	740	970	1190	1230	1230
E	140	250	710	--	--	--

For the 1973 short-term calculations, rawinsonde data taken at the Greater Pittsburgh Airport on the specific days of interest were plotted on a thermodynamic diagram. If an elevated inversion layer capped an adiabatic surface layer (such as on 4 January 1973), the mixing depth was set equal to the height above the airport of the base of the elevated inversion. If a surface-based inversion existed (such as on 18 January 1973), the minimum mixing depth was assumed to be 125 meters on the basis of our analysis of the Environmental Data Service (1966) tabulations of Pittsburgh early morning mixing depths. With a surface-based inversion, whenever the dry adiabat (line of constant potential temperature) passing through the surface temperature and pressure intersected the temperature profile at a height above the surface greater than 125 meters, the mixing depth was set equal to this height. If the surface temperature indicated that the surface-based inversion had been completely dissipated, the mixing layer was assumed to extend to the base of the next stable layer.

Section A 5 of Appendix A discusses the procedures for adjusting the Greater Pittsburgh Airport mixing depths for variations in terrain height over the calculation grid.

Ambient Air Temperatures

The Briggs (1971) plume-rise formulas given in Section A. 2 of Appendix A require the ambient air temperature as an input. For the seasonal concentration calculations, seasonal average afternoon temperatures measured at the Greater Pittsburgh Airport during the period 1963 through 1972 were assigned to the A, B and C stability categories; average morning and evening temperatures were assigned to the D stability category; and average nighttime temperatures were assigned to the combined E and F categories. Table 3-7 lists the ambient air temperatures used in the long-term calculations. Hourly surface temperatures measured at the Greater Pittsburgh Airport were used in the 1973 short-term calculations.

TABLE 3-7

AMBIENT AIR TEMPERATURES USED IN THE ANNUAL AVERAGE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Ambient Air Temperature (^oK)			
	Winter	Spring	Summer	Fall
A	273.2	287.0	298.3	289.5
B	273.2	287.0	298.3	289.5
C	273.2	287.0	298.3	289.5
D	271.2	283.7	294.4	286.3
E	269.7	280.3	290.7	282.4

TABLE 3-8

VERTICAL POTENTIAL TEMPERATURE GRADIENTS IN DEGREES KELVIN PER METER USED IN THE ANNUAL AVERAGE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind-Speed Category (m/sec)					
	0-1.5	1.6-3.1	3.2-5.1	5.2-8.2	8.3-10.8	>10.8
A	0.0	0.0	--	--	--	--
B	0.0	0.0	0.0	--	--	--
C	0.0	0.0	0.0	0.0	0.0	--
D	0.015	0.010	0.005	0.003	0.003	0.003
E	0.030	0.020	0.015	--	--	--

Vertical Potential Temperature Gradients

The Briggs (1971) plume-rise formulas given in Section A.2 of Appendix A also require the vertical potential temperature gradient as an input. Table 3-8 lists the vertical potential temperature gradients used in the long-term concentration calculations. The potential temperature gradients in Table 3-8 were assigned on the basis of the Turner (1964) and Pasquill (1961) definitions of the Pasquill stability categories, the measurements of Luna and Church (1971), and our own previous experience. For the 1973 short-term calculations, vertical potential temperature gradients were obtained from the rawinsonde measurements made at the Greater Pittsburgh Airport.

Wind Persistence Statistics

In selecting the meteorological inputs for the short-term compliance calculations, it was necessary to analyze the joint persistence of wind speed and wind direction at the Greater Pittsburgh Airport in order to assure that the worst-case conditions assumed in the calculations were realistic. Table 3-9 shows the total number of occurrences, during the period January 1963 through December 1972, of the persistence within each wind-direction sector of wind speeds above 3.1 meters per second for time periods from 1 to 24 hours. Table 3-10 shows, for the same 10-year period, the total number of occurrences of the persistence within each wind-direction sector of wind speeds greater than 5.1 meters per second for time periods from 1 to 24 hours.

TABLE 3-9

TOTAL NUMBER OF OCCURRENCES OF THE COMBINED PERSISTENCE OF WIND DIRECTIONS AND WIND SPEEDS ABOVE 3.1 METERS PER SECOND AT THE GREATER PITTSBURGH AIRPORT FOR THE PERIOD 1963-1972

Number of Hours of Persistence	Wind Direction (Sector)															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
≥1	4095	1209	1073	1371	1763	1674	1967	1341	2880	2647	5666	6750	8814	4966	4041	3145
≥2	1893	529	482	629	817	765	907	588	1330	1191	2621	3115	4187	2310	1841	1409
≥3	1217	327	307	402	524	497	590	369	851	755	1685	1985	2698	1471	1175	887
≥4	708	179	173	232	307	289	335	193	467	413	975	1148	1663	859	664	507
≥5	590	156	152	199	261	239	288	177	413	362	811	962	1337	719	562	415
≥6	577	153	150	195	256	234	283	176	409	356	787	934	1291	701	556	409
≥7	141	19	24	44	57	59	60	15	48	49	176	238	442	159	108	86
≥8	134	18	24	40	55	54	55	15	48	48	169	219	417	153	105	82
≥9	130	18	24	38	52	52	52	15	48	47	160	205	383	144	102	80
≥10	108	16	20	34	44	44	43	12	43	41	137	170	322	122	84	68
≥11	104	16	20	31	43	43	42	12	43	41	135	162	309	121	83	68
≥12	103	16	19	31	43	43	42	12	43	41	135	160	306	118	83	67
≥13	31	1	4	9	13	10	13	3	5	7	25	54	117	33	21	15
≥14	31	1	4	9	13	9	13	3	5	7	25	54	115	32	21	14
≥15	31	1	4	9	13	9	12	3	5	7	25	53	113	31	20	14
≥16	26	1	4	7	12	9	11	3	5	7	25	47	104	30	19	14
≥17	26	1	4	7	12	9	11	3	5	7	25	47	102	30	19	14
≥18	26	1	4	7	12	9	11	3	5	7	25	47	101	30	19	14
≥19	5	0	0	3	4	2	5	0	0	1	6	15	43	9	3	3
≥20	5	0	0	3	4	2	5	0	0	1	6	14	43	9	3	3
≥21	5	0	0	3	4	2	5	0	0	1	6	14	43	9	3	3
≥22	5	0	0	3	4	2	4	0	0	1	6	13	41	9	3	3
≥23	5	0	0	3	4	2	4	0	0	1	6	13	41	9	3	3
≥24	5	0	0	3	4	2	4	0	0	1	6	13	41	8	3	3

TABLE 3-10

TOTAL NUMBER OF OCCURRENCES OF THE COMBINED PERSISTENCE OF WIND DIRECTIONS AND WIND SPEEDS ABOVE 5.1 METERS PER SECOND AT THE GREATER PITTSBURGH AIRPORT FOR THE PERIOD 1963-1972

Number of Hours of Persistence	Wind Direction (Sector)															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
≥ 1	1168	234	177	295	285	397	463	278	752	1007	2846	3923	5507	3062	2086	1399
≥ 2	533	93	83	138	131	174	213	124	345	451	1305	1816	2605	1430	946	618
≥ 3	335	58	52	90	84	112	136	79	221	288	840	1153	1686	907	603	393
≥ 4	180	33	27	53	51	63	75	40	114	154	473	668	1032	530	345	215
≥ 5	163	29	26	44	41	53	67	39	108	139	405	562	829	442	289	194
≥ 6	161	28	26	43	41	52	67	39	107	139	389	539	806	429	284	192
≥ 7	16	5	2	12	8	12	11	1	6	16	67	125	249	94	54	29
≥ 8	14	5	2	11	8	12	10	1	6	16	66	116	239	90	54	28
≥ 9	13	5	2	10	8	12	10	1	6	16	64	107	221	85	53	28
≥10	13	4	1	9	8	10	7	1	5	14	55	95	191	74	44	24
≥11	13	4	1	8	8	10	7	1	5	14	55	91	187	74	44	24
≥12	12	4	1	8	8	10	7	1	5	14	55	90	186	73	44	24
≥13	1	1	1	2	0	2	3	0	1	2	9	23	56	15	8	4
≥14	1	1	1	2	0	2	3	0	1	2	9	23	54	15	8	3
≥15	0	1	1	2	0	2	3	0	1	2	9	22	54	14	8	3
≥16	0	1	1	2	0	2	3	0	1	2	9	20	50	14	8	3
≥17	0	1	1	2	0	2	3	0	1	2	9	19	49	14	8	3
≥18	0	1	1	2	0	2	3	0	1	2	9	19	49	14	8	3
≥19	0	0	0	1	0	0	0	0	0	0	1	8	21	3	1	0
≥20	0	0	0	1	0	0	0	0	0	0	1	8	21	3	1	0
≥21	0	0	0	1	0	0	0	0	0	0	1	8	21	3	1	0
≥22	0	0	0	1	0	0	0	0	0	0	1	7	21	3	1	0
≥23	0	0	0	1	0	0	0	0	0	0	1	7	21	3	1	0
≥24	0	0	0	1	0	0	0	0	0	0	1	7	21	3	1	0

SECTION 4

LONG-TERM MODEL CALCULATIONS FOR 1973

4.1 INTRODUCTION

To test the performance of the long-term concentration model described in Section A.4 of Appendix A, including the adjustments for terrain effects discussed in Section A.5, model calculations were made of the seasonal and annual average ground-level SO_2 concentrations for the year 1973 using SO_2 emissions data for various major source complexes located in the Pittsburgh area. This year was selected because it is the most recent year for which comprehensive emissions and air quality data are available.

Section 4.2 contains a detailed description of the calculation procedures as well as a discussion of the results of the 1973 annual calculations. The 1973 source data used in the calculations are presented in Section 4.3 and the meteorological inputs are discussed in Section 4.4.

4.2 CALCULATION PROCEDURES AND RESULTS

The source data given in Section 4.3 and the meteorological data discussed in Section 4.4 were used with the long-term concentration model described in Section A.4 of Appendix A to calculate seasonal and annual average ground-level SO_2 concentrations for 649 grid points on a 21-kilometer by 28-kilometer grid enclosed by the areas shown in Figures 4-1 and 4-2. The procedures described in Section A.5 of Appendix A were used to account for the effects of variations in terrain height over the calculation grid. It is important to note that we have not used any calibration constants to scale the calculated concentrations to concentrations observed at air quality monitoring sites. The model concentrations presented in

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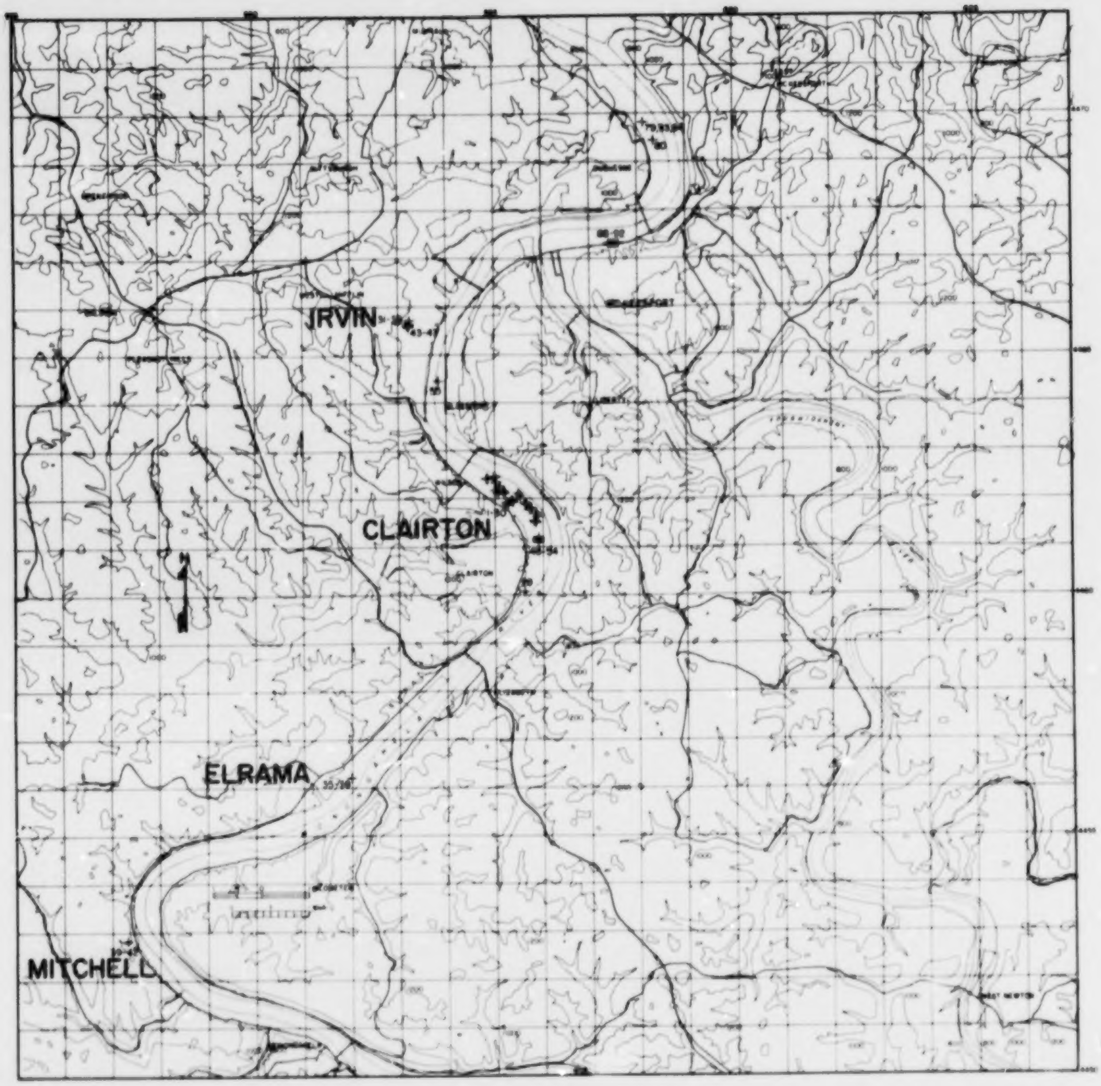
IRVIN
CLAIRTON
ELRAMA
MITCHELL

FIGURE 4-1. Topographic map of the Clairton-Liberty Borough area showing the locations of the major SO_2 sources. Elevations are in feet above mean sea level, and the contour interval is 200 feet (61 meters).

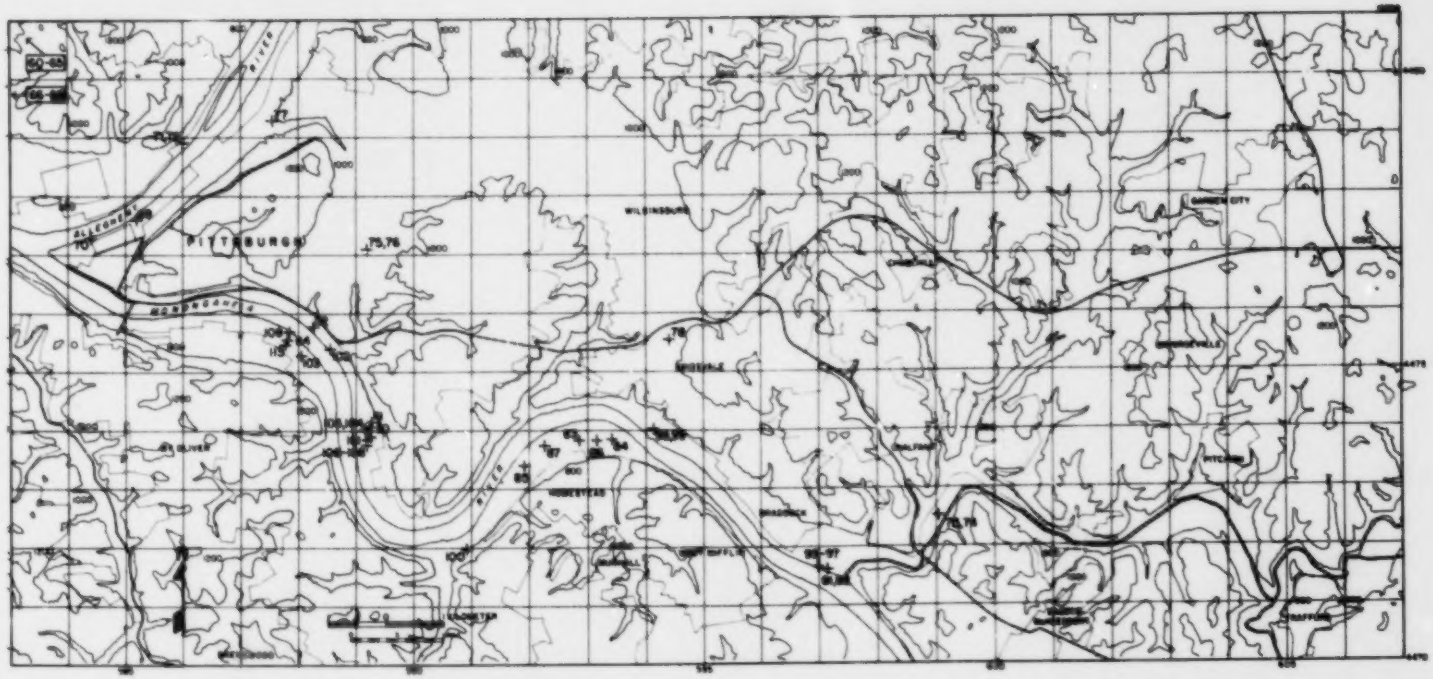
ALLEGHENY
RIVER
PITTSBURGH
MONONGAHELA
RIVER
WILKINSBURG
HOMESTEAD
BRADDOCK
75,76
77
78
101
115
103
87
85
84
1000

FIGURE 4-2. Topographic map of the Hazelwood-Braddock area showing the locations of the major SO_2 sources. Elevations are in feet above mean sea level, and the contour interval is 200 feet (61 meters).

this section have been calculated directly from the emissions data and meteorological data without any adjustments whatever to make them conform to observed air quality. Additionally, no background SO_2 concentrations have been incorporated in the calculated concentrations.

Figure 4-3 shows, for the combined sources, the calculated isopleths of annual average ground-level SO_2 concentration for the Clairton-Liberty Borough area. Neglecting the annual ambient SO_2 background concentration, Figure 4-3 indicates that the annual Primary Air Quality Standard of 80 micrograms per cubic meter was exceeded within a large area, centered on the west bank of the Monongahela River, that extends from the southern boundary of Allegheny County to the Liberty Borough area. The maximum annual average concentration calculated at a single grid point is 333 micrograms per cubic meter. This grid point is located on the elevated terrain northeast of the Clairton Coke Works (see Figure 4-3). Emissions from the Clairton Coke Works account for 90 percent of this calculated maximum. As shown by Figure 4-3, calculated annual average concentrations greater than or equal to 150 micrograms per cubic meter also occur in an area west of the Clairton Coke Works and in two other areas respectively located 2.5 kilometers north and northeast of the Elrama power plant. In the area west of the Clairton Coke Works, emissions from the Elrama power plant, the Mitchell power plant and the Clairton Coke Works account for 16, 5 and 76 percent, respectively, of the calculated maximum concentration of 168 micrograms per cubic meter. In the area 2.5 kilometers north of the Elrama power plant, the contributions of Elrama, Mitchell and the Clairton Coke Works to the maximum calculated concentration of 240 micrograms per cubic meter are 86, 7 and 4 percent, respectively. Finally, emissions from Elrama, Mitchell and the Clairton Coke Works account for 80, 10 and 6 percent, respectively, of the maximum calculated concentration of 156 micrograms per cubic meter in the region 2.5 kilometers northeast of Elrama.

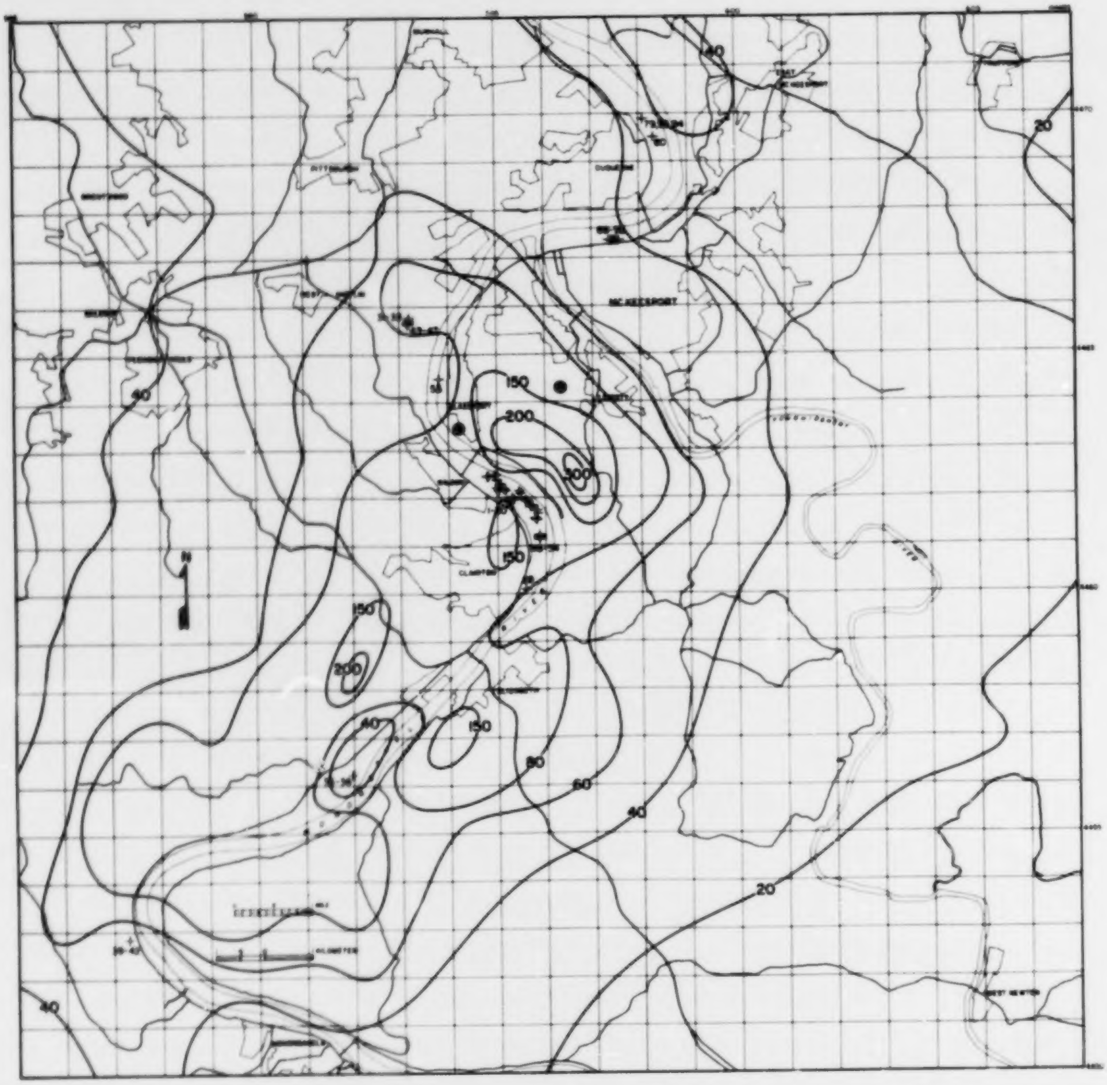
40
20
150
200
300
150
150
200
150
80
60
40
20
40
40

FIGURE 4-3. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter for the Clairton-Liberty Borough area during 1973. The filled circles show the locations of the Glassport and Liberty Borough SO_2 monitors.

Table 4-1 lists, for the major source complexes independently and for all sources combined, the annual average ground-level SO_2 concentrations calculated for the Glassport and Liberty Borough monitors. The locations of the two monitors are shown by the filled circles in Figure 4-3. The calculated annual average concentration for the Glassport monitor is 80 micrograms per cubic meter, which is approximately equal to the annual average concentration of 79 micrograms per cubic meter measured by the monitor. Emissions from the Clairton Coke Works account for about 62 percent of the calculated total, while emissions from the Elrama and Mitchell power plants contribute 20 and 8 percent, respectively. The calculated annual average concentration at the Liberty Borough monitor is 116 micrograms per cubic meter, which is approximately 83 percent of the annual average concentration of 139 micrograms per cubic meter measured by the monitor. As shown by Table 4-1, the Clairton Coke Works is responsible for about 76 percent of the annual average concentration calculated for the Liberty Borough monitor. The Elrama and Mitchell power plants contribute an additional 12 and 5 percent, respectively.

Figure 4-4 shows, for the combined sources, the calculated isopleths of annual average ground-level SO_2 concentration for the Hazelwood-Braddock area. Neglecting the annual ambient SO_2 background, Figure 4-4 indicates that the annual standard was also exceeded over a large portion of the Hazelwood area. Two grid points have essentially identical calculated concentrations. In the crescent-shaped area where the Monongahela River dips to the south, the calculated maximum concentration is 287 micrograms per cubic meter. Emissions from the Jones and Laughlin plant account for 89 percent of this calculated concentration. The second maximum calculated concentration in the Hazelwood area is located 3 kilometers east of the first maximum. Emissions from the U. S. Steel Homestead plant account for 85 percent of the calculated concentration of 288 micrograms per cubic meter.

TABLE 4-1

CALCULATED 1973 ANNUAL AVERAGE GROUND-LEVEL SO_2 CONCENTRATIONS AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITORS

Source	Annual Average Concentration ($\mu g/m^3$)			
	Glassport Monitor		Liberty Borough Monitor	
Clairton				
Coke Ovens	18.7 (23%)		37.6 (32%)	
Power Boilers	17.5 (22%)		26.1 (23%)	
Reheat and Blast Furnaces	3.2 (4%)		2.5 (2%)	
Claus Plant	9.9 (12%)		21.6 (19%)	
All Sources		49.3 (62%)		87.8 (76%)
Irvin				
Process	1.5 (2%)		1.3 (1%)	
Reheat	2.3 (3%)		1.2 (2%)	
All Sources		3.8 (5%)		2.5 (2%)
Elrama		16.2 (20%)		13.8 (12%)
Mitchell		6.1 (8%)		6.3 (5%)
Pittron		0.0 (0%)		0.1 (0%)
Others		4.7 (6%)		5.2 (4%)
Combined Sources		80.1 (100%)		115.7 (100%)

*Numbers inclosed in parentheses show the percentage of the total calculated concentration allocated to each source.

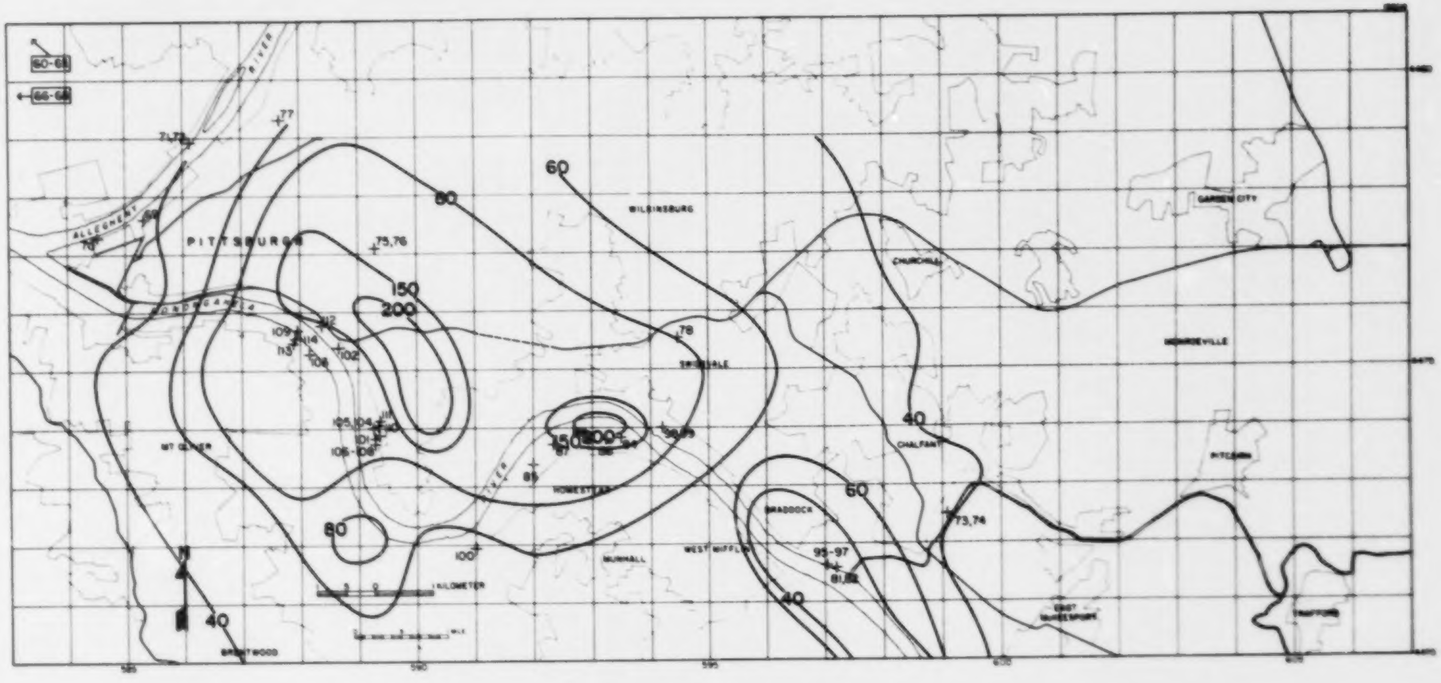
60-61
66-68
ALLEGHENY
RIVER
MONONGAHELA
PITTSBURGH
WILKINSBURG
CHURCHILL
GARDEN CITY
MONROEVILLE
SWISSVALE
CHALFANT
PITCAIRN
HOMESTEAD
BRADDOCK
MUNHALL
WEST MIFFLIN
EAST McKEESPORT
TRAFFORD
MT OLIVER
BRENTWOOD
1 KILOMETER
60
80
150
200
80
150
200
60
40
60
40
40
77
71,72
69
70
75,76
112
109
114
113
108
102
105,104
101
106-108
111
110
78
87
86
94
98,99
85
100
73,74
95-97
81,82
585
590
595
600
605

FIGURE 4-4. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter for the Hazelwood-Braddock area during 1973.

4.3 SOURCE DATA

Table 4-2 lists the sources, source locations, SO_2 emission rates and stack parameters that were used to calculate annual average ground-level SO_2 concentrations for 1973. These parameters were taken directly from the emissions inventory and other data supplied by the Allegheny County Bureau of Air Pollution Control. The locations of all sources are reported in Universal Transverse Mercator (UTM) coordinates which were individually checked prior to their being used in the model calculations. Figures 4-1 and 4-2 show the locations of the sources used in the model calculations on topographic maps of the Clairton-Liberty Borough and Hazelwood-Braddock areas, respectively. As previously noted, the ambient SO_2 background and the contributions of sources other than the sources listed in Table 4-2 were not included in the calculations for 1973.

A check of the emissions data reported for the United States Steel facilities were made using fuel data from various reports and other information provided by the Allegheny County Bureau of Air Pollution Control. The results of these checks are summarized in Table 4-3. Discrepancies between the calculated and reported emissions appear to be minor and within the accuracies of the assumptions that were used in the calculations.

4.4 METEOROLOGICAL DATA

The general meteorological inputs (turbulent intensities, wind-profile exponents, median mixing depths, ambient air temperatures and vertical potential temperature gradients) used in the 1973 seasonal and annual concentration calculations are discussed in Section 3. In addition to these inputs, the long-term concentration model requires seasonal distributions of wind-speed and wind direction categories. These distributions were developed from airport surface weather observations by the National Climatic Center's STAR program which is based on

TABLE 4-2

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE ANNUAL AND SEASONAL AMBIENT AIR QUALITY FOR 1973

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
1 Clairton Underfire #1	595, 860	4, 461, 520	578	69	700	37. 27	1. 220
2 Clairton Underfire #2	595, 830	4, 461, 540	578	69	700	37. 27	1. 220
3 Clairton Underfire #3	595, 730	4, 461, 780	578	69	700	37. 27	1. 220
7 Clairton Underfire #7	595, 880	4, 461, 650	578	65	700	35. 87	1. 270
8 Clairton Underfire #8	595, 870	4, 461, 680	578	65	700	35. 87	1. 270
9 Clairton Underfire #9	595, 750	4, 461, 810	578	65	700	35. 87	1. 270
10 Clairton Underfire #10	595, 660	4, 461, 900	578	69	700	37. 27	1. 220
11 Clairton Underfire #11	595, 630	4, 461, 920	578	69	700	37. 27	1. 220
12 Clairton Underfire #12	595, 520	4, 462, 060	578	69	700	37. 27	1. 220
13 Clairton Underfire #13	595, 380	4, 461, 930	578	69	700	37. 74	1. 310
14 Clairton Underfire #14	595, 360	4, 461, 960	578	69	700	37. 74	1. 310
15 Clairton Underfire #15	595, 210	4, 462, 110	578	69	700	37. 74	1. 310
16 Clairton Underfire #16	595, 190	4, 462, 150	578	61	700	32. 13	1. 310
17 Clairton Underfire #17	595, 110	4, 462, 240	578	61	700	32. 13	1. 310

TABLE 4-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
18 Clairton Underfire #18	595,020	4,462,330	578	76	700	32.300	1.460
19 Clairton Underfire #19	595,280	4,461,880	578	76	700	58.430	2.140
20 Clairton Underfire #20	595,250	4,461,910	578	76	700	58.430	2.140
21 Clairton Underfire #21	595,060	4,462,120	578	76	700	58.430	2.140
22 Clairton Underfire #22	595,030	4,462,160	578	76	700	58.430	2.140
23 Clairton Underfire #12A	595,500	4,462,080	578	69	700	35.870	1.520
24 Clairton B&W #1	595,000	4,462,470	3,730	50	455	92.570	1.370
25 Clairton CE #2	595,000	4,462,470	1,175	50	455	72.330	1.060
26 Clairton Benzene Boiler	594,870	4,462,400	588	52	16*	60.000*	--
27 Clairton Benzene Boiler	594,850	4,462,410	588	52	16*	60.000*	--
28 Clairton Blast Furnace	595,630	4,460,060	303	60	716	180.580	1.880
30 Clairton Claus Plant	595,810	4,461,550	5,074	46	561	18.030	.610
31 Irvin 3 and 4	593,220	4,465,600	824	55	646	54.550	1.790
32 Irvin 5 and 6	593,230	4,465,650	1,232	78	633	79.620	1.600
33 Irvin 7	593,250	4,465,710	937	30	483	33.400	.920
35 Elrama	592,000	4,456,200	12,079	83	416	198.950	2.150

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 4-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
36 Elrama	592,000	4,456,200	12,079	83	430	198.950	2.150
37 Elrama	592,000	4,456,200	13,920	83	430	229.450	2.150
38 Elrama	592,000	4,456,200	20.935	89	416	299.140	2.300
39 Mitchell	587,340	4,452,810	27,142	73	403	534.810	3.050
40 Mitchell	587,340	4,452,810	6,769	70	467	223.640	2.150
41 Mitchell	587,340	4,452,810	6,769	70	467	223.640	2.150
42 Mitchell	587,340	4,452,810	6,769	70	467	223.640	2.150
43 Irvin Reheat	593,250	4,465,600	365	52	10*	50.000*	--
44 Irvin Reheat	593,250	4,465,700	365	52	10*	50.000*	--
45 Irvin Reheat	593,250	4,465,650	365	52	10*	50.000*	--
46 Irvin Reheat	593,260	4,465,600	365	52	10*	50.000*	--
47 Irvin Reheat	593,260	4,465,650	365	52	10*	50.000*	--
48 Clairton Reheat	595,100	4,461,520	131	52	70*	70.000*	--
49 Clairton Reheat	595,100	4,461,530	131	52	70*	70.000*	--
50 Clairton Reheat	595,100	4,461,540	131	52	70*	70.000*	--
51 Clairton Reheat	595,100	4,461,500	131	52	70*	70.000*	--

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 4-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
52 Clairton Reheat	595,100	4,461,560	131	52	70*	70.000*	--
53 Clairton Reheat	595,100	4,461,570	131	52	70*	70.000*	--
54 Clairton Reheat	595,100	4,461,580	131	52	70*	70.000*	--
55 **Pittron**	593,850	4,464,500	39	75	600	88.000	2.000
60 Phillips Power Station	565,260	4,491,020	3,217	76	461	83.460	1.800
61 Phillips Power Station	565,260	4,491,020	3,216	76	461	83.460	1.800
62 Phillips Power Station	565,260	4,491,020	5,307	76	457	118.070	1.800
63 Phillips Power Station	565,260	4,491,020	5,307	76	457	118.070	1.800
64 Phillips Power Station	565,260	4,491,020	5,307	76	457	118.070	1.800
65 Phillips Power Station	565,260	4,491,020	8,524	49	430	167.850	2.300
66 Brunots Island Turbines	580,680	4,479,680	28	10	735	237.600	.900
67 Brunots Island Turbines	580,730	4,479,720	28	10	735	237.600	.900
68 Brunots Island Turbines	580,770	4,479,750	28	10	735	237.600	.900
69 12th Street Steam	585,200	4,477,600	1,179	82	604	108.260	2.000
70 Stanwix Street Steam	584,380	4,477,300	1,040	112	574	227.230	2.600
71 H. J. Heinz Co.	586,000	4,478,900	745	76	473	18.730	1.500

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 4-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
72 H. J. Heinz Co.	586,000	4,473,900	745	76	473	16.290	1.500
73 Westinghouse Electric	599,020	4,472,550	110	50	505	17.420	1.100
74 Westinghouse Electric	599,020	4,472,550	110	37	461	7.470	1.000
75 Bellefield Boilers	589,190	4,477,100	464	59	589	26.950	1.400
76 Bellefield Boilers	589,190	4,477,100	460	69	561	24.150	1.700
77 Pittsburgh Brewery	587,550	4,479,280	365	63	472	39.560	1.200
78 WABCO	594,400	4,475,550	135	27	569	19.310	.700
79 Duquesne N C Boilers	598,120	4,469,830	157	49	551	32.870	1.100
80 Duquesne Reheat	598,360	4,469,450	402	37	700	26.300	.900
81 E. T. N C Boilers	597,110	4,471,610	73	33	551	26.230	1.200
82 E. T. Soaking Pits	597,440	4,471,870	402	30	764	22.320	.800
83 Homestead N C Boilers	592,850	4,473,830	15	16	361	25.040	1.600
84 Homestead Process 1	593,400	4,473,870	1,376	32	50*	100.000*	--
85 Homestead Process 2	591,900	4,473,400	1,376	32	50*	100.000*	--
86 Homestead Process 3	593,150	4,473,850	1,376	32	50*	100.000*	--
87 Homestead #5 OH	592,350	4,473,750	1,515	38	532	153.930	2.000

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 4-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
88 National #1	597,400	4,467,330	124	46	590	39.250	1.300
89 National #2	597,450	4,467,330	124	46	590	39.250	1.300
90 National #3	597,500	4,467,330	124	46	590	39.250	1.300
91 National #4	597,550	4,467,330	124	46	590	39.250	1.300
92 National #5	597,600	4,467,330	124	46	590	39.250	1.300
93 Duquesne #15	598,120	4,469,830	124	49	551	32.870	1.100
94 Duquesne #17	598,120	4,469,830	394	49	551	32.870	1.100
95 E. T. #1	596,990	4,471,670	456	50	533	121.550	2.100
96 E. T. #2	596,990	4,471,670	456	50	533	121.550	2.100
97 E. T. #3	596,990	4,471,670	456	50	533	121.550	2.100
98 Homestead Carrie #3	594,120	4,474,020	927	43	561	200.320	2.400
99 Homestead Carrie #4	594,120	4,474,020	751	43	561	154.030	1.900
100 Mesta Machine Co.	590,920	4,471,980	402	61	511	7.360	.900
101 J & L By Products Boilers	589,250	4,473,900	2,332	24.4	616	6.150	.680
102 J & L Eliza Boilers	588,560	4,475,400	1,612	36.6	477	66.630	1.340
103 J & L South Side Boilers	588,030	4,475,280	2,929	35.7	477	26.650	1.220

TABLE 4-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
104 J & L Underfire #1	589,150	4,474,030	1,572	61	600	32.140	1.300
105 J & L Underfire #2	589,150	4,474,020	1,564	62.6	600	31.700	1.450
106 J & L Underfire #3	589,190	4,473,860	1,544	62.6	600	31.700	1.450
107 J & L Underfire #4	589,190	4,473,840	1,544	62.6	600	31.700	1.450
108 J & L Underfire #5	589,200	4,473,750	1,832	62.6	600	31.700	1.450
109 J & L Open Hearth	587,850	4,475,680	1,742	38	532	153.950	1.980
110 J & L Barmill #1	589,240	4,474,060	707	38.1	727	20.400	.840
111 J & L Barmill #2	589,260	4,474,150	554	38.1	727	24.900	1.070
112 J & L Stripmill	588,265	4,475,775	2,523	18.0	727	47.420	1.300
113 J & L Soaking Pits	587,780	4,475,470	2,024	48	727	4.850	.860
114 J & L Soaking Pits	587,800	4,475,550	1,241	34	727	2.920	.780

TABLE 4-3

REPORTED AND CALCULATED 1973 EMISSIONS FOR U. S. STEEL FACILITIES

PLANT COMPONENT	COMPONENT FUEL USAGE JAN-SEP 1973 (10^9 BTU/month)									SO_2 EMISSIONS JAN-SEP 1973 (tons/day)	
	BFG	Pure Cog	Total Natural Gas or		Coal	Fuel Oil	Benzene Product	PTM	Total	Reported	Calc'd
			N. Gas in Mixed Cog	Direct Natural Gas							
Clairton	< 320	2830	0	913	538	3	12	0>	4,616	<51.60>	<51.42>
B&W #1	-	109	-	-	342	-	12	-		10.22	10.84
CE #2	-	116	-	3	152	-	-	-		3.22	4.96
Benezene Boilers #13, #14	-	39	-	-	44	-	-	-		3.22	1.85
Blast F Boilers	320	30	-	-	-	[3]	-	-		0.83	0.14
Reheat	-	203	-	Ammonia [910] Plant	-		-	-		2.51	0.88
Underfire C. O.	-	2333	-		-		-	-		31.60	32.75
Irvin	< 0	208	0	258	142	485	0	0>	1,093	<13.2>	<10.56>
Boilers #3-7	-	125	-	-	142	-	-	-		8.2	6.49
Reheat	-	83	-	258	-	485	-	-		5.0	4.07
National	< 95	326	58	77	40	0	0	0>	596	<1.7>	<2.20>
Boilers #1-5	69	90	16	29	40	-	-	-		1.7	1.12
N-C Boilers*	26	-	-	-	-	-	-	-		N/R	0
Process*	-	236	42	48	-	-	-	-		N/R	1.08

*No Emissions Reported

<> Indicates sum of total source complex emissions or fuel usage

[ ] Indicates aggregate process fuel usage

TABLE 4-3 (Continued)

PLANT COMPONENT	COMPONENT FUEL USAGE JAN-SEP 1973 (10^9 BTU/month)									SO$_2$ EMISSIONS JAN-SEP 1973 (tons/day)	
	BFG	Pure Cog	Total Natural Gas or: N. Gas in Mixed Cog	Total Natural Gas or: Direct Natural Gas	Coal	Fuel Oil	Benzene Product	PTM	Total	Reported	Calc'd
Duquesne	< 937	157.8	28	347	86	49	0	0>	1,605	<4.31>	<4.70>
Boiler #15	-	[26.4]	[4.7]	[6]	86]	-	-	-		1.70	1.86
Boiler #17	-					-	-	-		1.08	1.86
N-C Boilers	937	54.4	[3.3]		-	37.2	-	-		0.43	0.54
Reheat	-	77	[361]		-	11.8	-	-		1.10	0.44
Edgar Thomson	<1384	134.3	34	241	47	1	0	0>	1,841	<3.8>	<2.59>
Boilers #1-3	621	20.4	3.6	6	47	-	-	-		2.5	2.06
N-C Boilers	763	28.9	[91.4]		-	1	-	-		0.2	0.14
Soaking Pits	-	85	[174]		-		-	-		1.1	0.39
Homestead	<1109	1049	185	266	44	491.4	0	422>	3,566	<20.10>	<16.71>
Carrie #3 Reilly	271	118.1	20.9	34	22	-	-	-		2.62	1.27
Carrie #4 Reilly	242	45.9	8.1	17	22	-	-	-		1.98	0.94
N-C Boilers OH	596	32.3	[37.7]		-	34.4	-			0.04	0.42
Process 1 Reheat	-	[852.6]	[332.9]		-	[457]	-	[422]		3.77	3.31
Process 2 Reheat	-				-		-			3.77	3.31
Process 3 Reheat	-				-		-			3.77	3.31
#5 Open Hearth	-				-		-			4.15	4.15

PLANT COMPONENT	COMPONENT FUEL USAGE JAN-SEP 1973 (10^9 BTU/month)									SO_2 EMISSIONS JAN-SEP 1973 (tons/day)	
	BFG	Pure Cog	Total Natural Gas or		Coal	Fuel Oil	Benzene Product	PTM	Total	Reported	Calc'd
			N. Gas in Mixed Cog	Direct Natural Gas							
Total	<3845	4705	305	2102	897	1029	12	422>	13,317	<94.71>	<88.18>
Additional: Clairton Claus Plant Stack	-	To Be Replaced By 1975					-	-	-	13.9	

the Turner (1964) definitions of the Pasquill stability categories (see Section 3.2). Figure 4-5 compares the 1973 annual frequency distributions of wind direction at the Greater Pittsburgh Airport (dashed line) and Allegheny County Airport (solid line). Inspection of the figure shows that, although the two distributions are generally similar, the most frequent winds at the Greater Pittsburgh Airport are from the west while those at the Allegheny County Airport are from the south and west-southwest. Because the Allegheny County Airport wind data are believed to be more representative of the wind circulation over most of the area of concern, hourly surface wind observations at Allegheny County Airport were used in conjunction with cloud cover observations from the Greater Pittsburgh Airport (no cloud cover data were available for Allegheny County Airport) to generate the seasonal wind distributions used in the 1973 seasonal and annual average concentration calculations. The Greater Pittsburgh Airport surface weather observations were recorded only once every 3 hours, and it was necessary to assume that the cloud cover remained constant over the 3-hour period. The resulting distributions of wind-speed and wind-direction categories, classified according to the Pasquill stability categories, are listed in Appendix B.

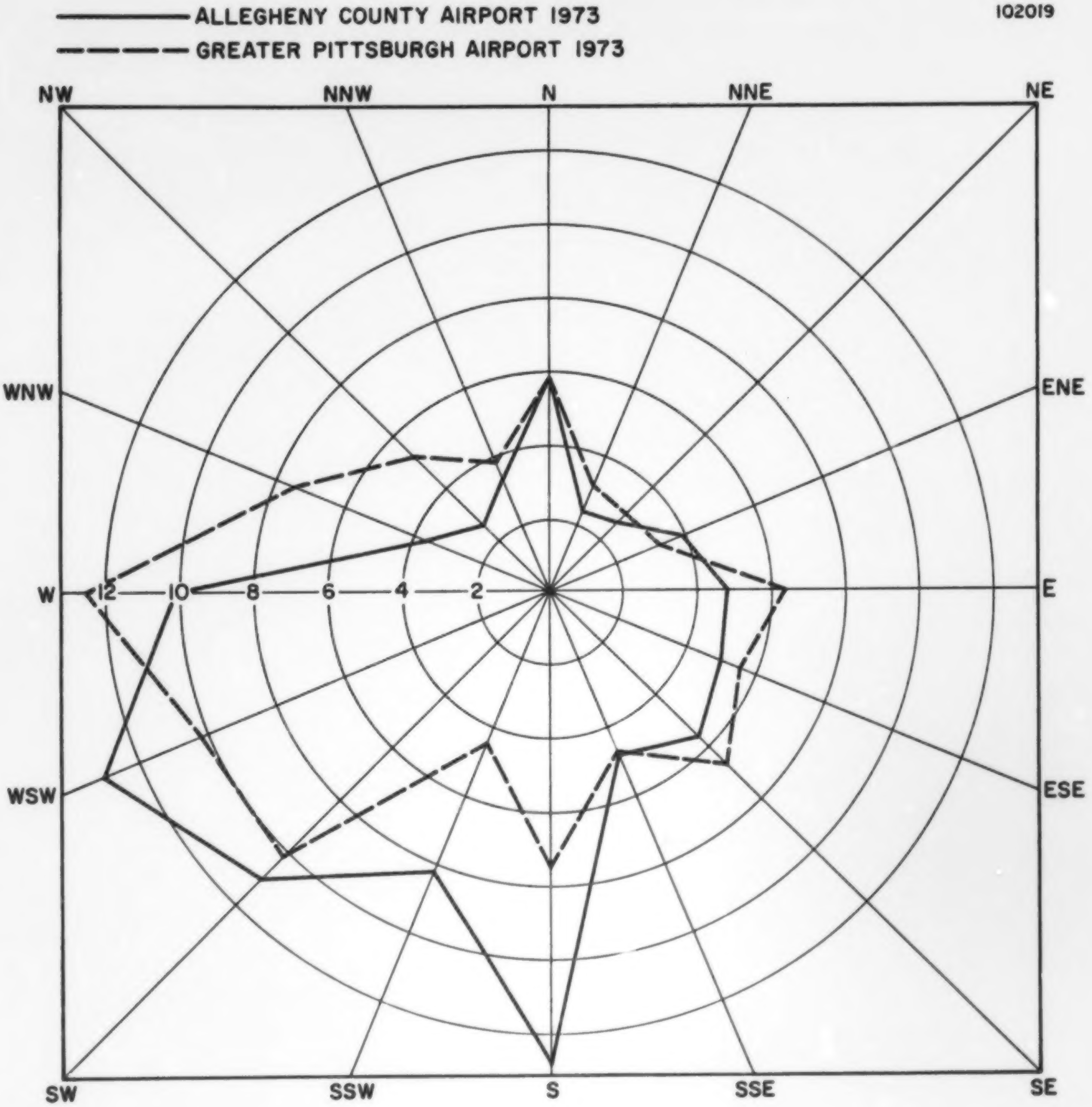

FIGURE 4-5. Annual frequency distributions of wind direction during 1973 at Allegheny County Airport (solid line) and the Greater Pittsburgh Airport (dashed line). Percent frequency scale is shown at left center.

SECTION 5

ANNUAL COMPLIANCE CALCULATIONS

5.1 INTRODUCTION

A major purpose of this study is to calculate by means of an appropriate diffusion model the maximum annual average ground-level SO_2 concentration that may be expected to occur in Allegheny County under the current SO_2 emission regulations for large stationary sources. The results of these calculations will assist the U. S. Environmental Protection Agency in determining the extent to which the current emission regulations will ensure the attainment and maintenance of the annual Primary Air Quality Standard of 80 micrograms per cubic meter.

Projected SO_2 emission rates reflecting the current emissions regulations were supplied by the Allegheny County Bureau of Air Pollution Control. These projected emission rates assume that all boilers are operated at capacity. Because of the complexity of the fuel distribution system supplying the U. S. Steel facilities, a number of varying emission rates are possible within the scope of the regulations. These variations result from changes in the supply of natural gas available to U. S. Steel and the decisions made by U. S. Steel on where to burn coke oven gas and where to make up any deficiencies in the supply of natural gas by burning coal in the many boilers in the six production facilities located along the Monongahela River.

The Allegheny County Bureau of Air Pollution Control has supplied SO_2 emissions data for three Compliance Cases (A, B and C) covering the major SO_2 sources within Allegheny County. These Compliance Cases differ only in the assumptions made with respect to the utilization of coke oven gas by the U. S. Steel facilities. Compliance Case A reflects the traditional U. S. Steel utilization of downriver coke oven gas with no curtailment of the 1973 natural gas supply in which 33 percent of the coke oven gas is consumed in boilers and 67 percent is used for process heating.

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In Compliance Case B, it is assumed that only 21 percent of the coke oven gas is available for use in boilers as a result of a partial curtailment of the natural gas supply. In Compliance Case C, a severe natural gas curtailment is assumed in which all of the coke oven gas normally used in the boilers is required for process heating. These changes in the utilization of coke oven gas have only a small effect on the total SO_2 emissions from the boilers and process heating units in the various U. S. Steel facilities. For example, the total SO_2 emissions in tons per day from all U. S. Steel boilers and process heating units for the three Compliance Cases are: Case A - 23.78; Case B - 25.38; and Case C - 26.85. Because these Compliance Case SO_2 emissions from the boilers and process heating units comprise less than 33 percent of the total SO_2 emissions from any U. S. Steel production facility, the total SO_2 emissions from any facility for the three Compliance Cases differ by only a few percent.

Diffusion model calculations made using the emissions data for the three Compliance Cases showed that the calculated ground-level SO_2 concentrations for the three cases were identical for all practical purposes. This result was to be expected from the above discussion of the small variation among the Compliance Cases in the SO_2 emission rates from boilers and process heating units and in the total SO_2 emissions from all sources. For these reasons, only the diffusion-model calculations made with the projected emissions data for Compliance Case A have been presented in this report.

The calculation procedures and the results of the annual compliance calculations are described in Section 5.2. The compliance case emissions data and the meteorological data used in the calculations are described in Sections 5.3 and 5.4.

5.2 CALCULATION PROCEDURES AND RESULTS

The meteorological data in Section 5.4 and the project SO_2 emissions data in Section 5.3 were used with the long-term concentration model described in

Section A.4 of Appendix A to calculate seasonal and annual average ground-level SO_2 concentrations for 649 grid points on a 21-kilometer by 28-kilometer grid enclosed by the areas shown in Figures 5-1 and 5-2. The model calculations provided for variations in terrain elevation over the calculation grid, as explained in Section A.5 of Appendix A.

Figures 5-1 and 5-2 show, for the combined sources, the calculated isopleths of annual average ground-level SO_2 concentration in the Clairton-Liberty Borough and Hazelwood-Braddock areas, respectively. Neglecting the annual ambient background, Figure 5-1 indicates that the annual Primary Air Quality Standard of 80 micrograms per cubic meter will be exceeded in an area bounded by Clairton, Glassport and Liberty Borough. The maximum calculated concentration in the Clairton-Liberty Borough area of 120 micrograms per cubic meter is located on elevated terrain along the east bank of the Monongahela River. Emissions from the Clairton Coke Works account for about 85 percent of this calculated maximum. Similarly, the calculated concentration isopleths in Figure 5-2 indicate that the annual standard may also be exceeded in small areas near Hazelwood and Homestead and in an area of several square kilometers located east of Braddock. The maximum ground-level concentration calculated in this area is 156 micrograms per cubic meter. Emissions from Westinghouse Electric account for 80 percent of this calculated maximum concentration.

Table 5-1 lists, for the major source complexes independently and for the combined sources, the annual average ground-level SO_2 concentrations calculated for the Glassport and Liberty Borough SO_2 monitors. The locations of the two monitors are shown by filled circles in Figure 5-1. The calculated annual average concentrations for the two monitors are below the annual Primary Air Quality

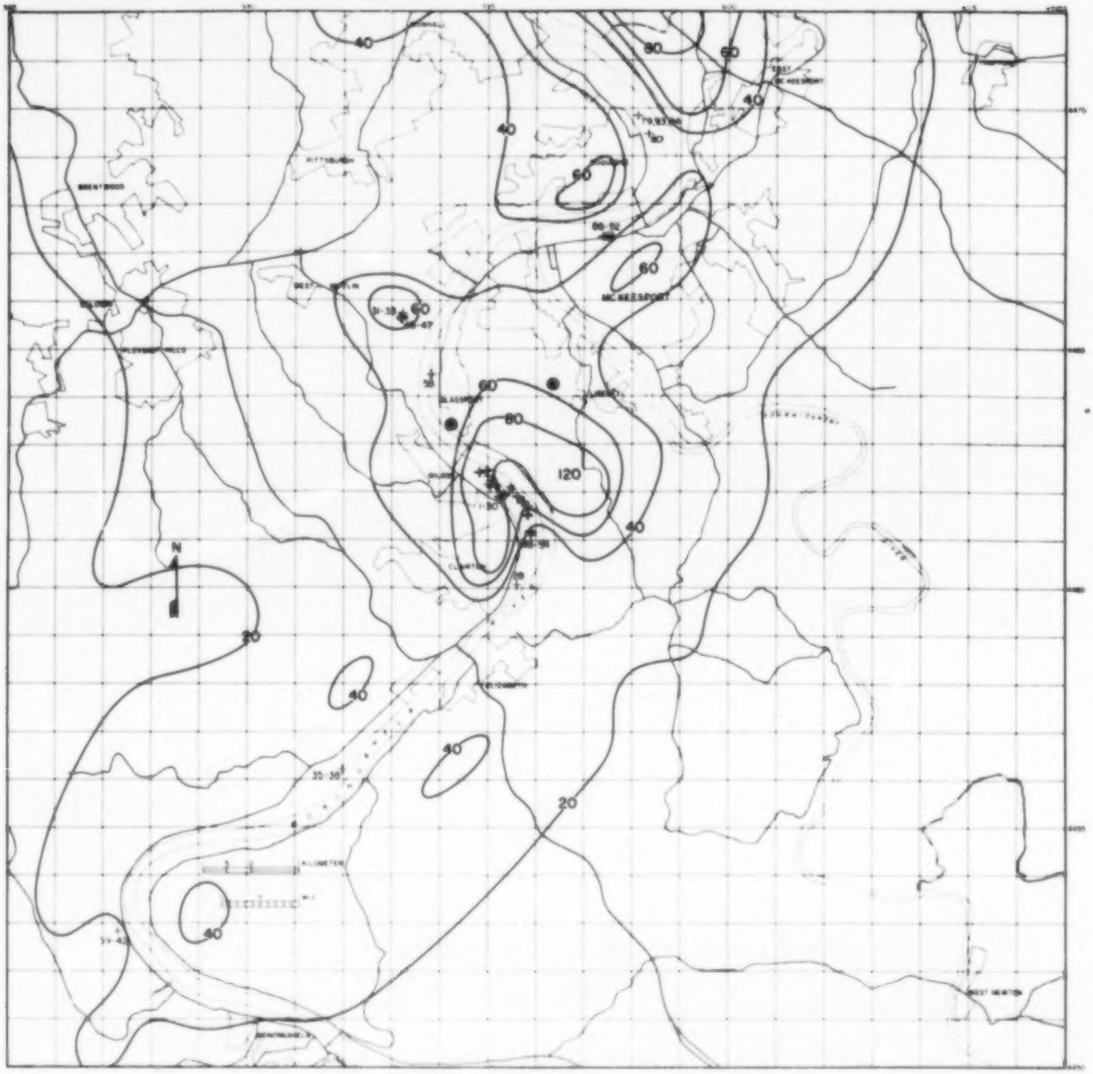
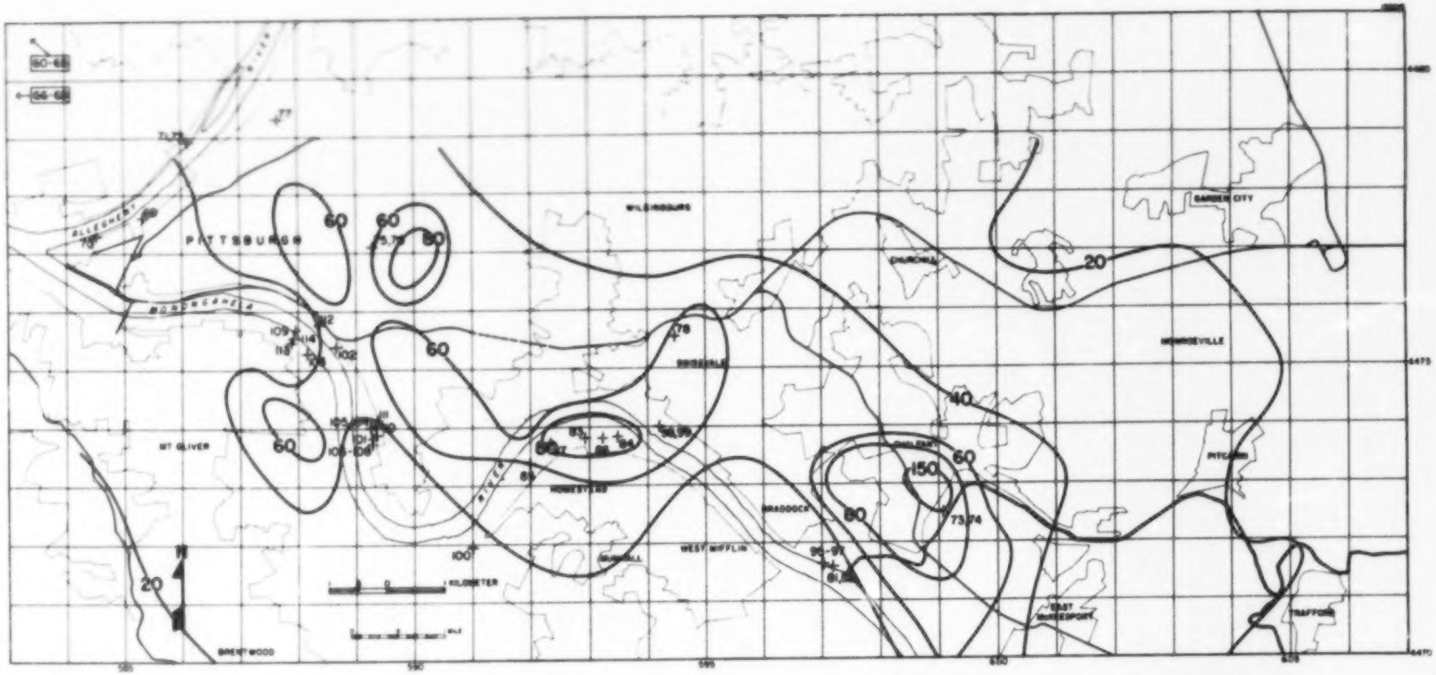

40
80
60
40
40
60
60
McKEESPORT
60
60
80
120
40
N
20
40
40
20
40

FIGURE 5-1. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter for the Clairton-Liberty Borough area under Compliance Case A. The two filled circles show the locations of the Glassport and Liberty Borough SO_2 monitors.



PITTSBURGH
ALLEGHENY
MONONGAHELA
MT OLIVER
BRENTWOOD
WILKINSBURG
CHURCHILL
MONROEVILLE
GARDEN CITY
PITCAIRN
TRAFFORD
EAST McKEESPORT
BRADDOCK
WEST MIFFLIN
MUNHALL
HOMESTEAD
SWISSVALE
RIVER
KILOMETER
20
40
60
80
150

FIGURE 5-2. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter for the Hazelwood-Braddock are under Compliance Case A.

TABLE 5-1

ANNUAL AVERAGE GROUND-LEVEL SO_2 CONCENTRATION CALCULATED AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITORS FOR COMPLIANCE CASE A

Source	Annual Average Concentration ($\mu g/m^3$)			
	Glassport Monitor		Liberty Borough Monitor	
Clairton				
Coke Ovens	3.2 (8%)		5.7 (11%)	
Power Boilers	20.1 (48%)		20.6 (38%)	
Reheat and Blast Furnaces	4.7 (11%)		5.4 (10%)	
Claus Plant	3.2 (8%)		4.5 (8%)	
All Sources		31.3 (75%)		36.3 (68%)
Irvin				
Process	1.3 (3%)		2.4 (5%)	
Reheat	0.9 (2%)		1.3 (2%)	
All Sources		2.2 (5%)		3.7 (7%)
Elrama		2.4 (6%)		2.5 (5%)
Mitchell		1.5 (4%)		1.8 (3%)
Pittron		0.0 (0%)		0.1 (0%)
Others		4.3 (10%)		9.4 (18%)
Combined Sources		41.7 (100%)		53.7 (100%)

*Numbers inclosed in parentheses show the percentage of the total calculated concentration allocated to each source.

Standard. Emissions from the Clairton Coke Works account for about 75 percent of the calculated average annual concentration at the Glassport monitor and for about 68 percent of the calculated average annual concentration at the Liberty Borough monitor.

5.3 SOURCE DATA

Table 5-2 lists the sources, source locations, SO_2 emission rates and stack parameters that were used to calculate annual average ground-level SO_2 concentrations for the compliance case. The parameter values in Table 5-2 were directly obtained from the inventory of projected emissions supplied by the Allegheny County Bureau of Air Pollution Control. The locations of the sources used in the model calculations are shown in Figures 5-1, 5-2 and on topographic maps in Figures 4-1 and 4-2 of Section 4. It should be noted that the ambient SO_2 background and the contributions of sources other than the sources listed in Table 5-2 were not considered in the compliance calculations.

5.4 METEOROLOGICAL DATA

The general meteorological inputs (turbulent intensities, wind-profile exponents, median mixing depths, ambient air temperatures and vertical potential temperature gradients) used in the annual compliance calculations are given in Section 3. Seasonal distributions of wind-speed and wind-direction obtained from hourly surface observations at the Greater Pittsburgh Airport for the year 1965 and classified by Pasquill stability categories were used in the annual compliance case calculations. These distributions are listed in Appendix B. The year 1965 was selected for the compliance calculations because Rubin (1974), using the Air Quality Display Model (Environmental Protection Agency, 1969) to calculate annual average ground-level SO_2 concentrations in Allegheny County for the years

TABLE 5-2

PROJECTED SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO PREDICT ANNUAL AND SEASONAL AMBIENT AIR QUALITY FOR COMPLIANCE CASE A

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
1 Clairton Underfire #1	595,860	4,461,520	120	69	700	37.27	1.220
2 Clairton Underfire #2	595,830	4,461,540	120	69	700	37.27	1.220
3 Clairton Underfire #3	595,730	4,461,780	120	69	700	37.27	1.220
7 Clairton Underfire #7	595,880	4,461,650	120	65	700	35.87	1.270
8 Clairton Underfire #8	595,870	4,461,680	120	65	700	35.87	1.270
9 Clairton Underfire #9	595,750	4,461,810	120	65	700	35.87	1.270
10 Clairton Underfire #10	595,660	4,461,900	120	69	700	37.27	1.220
11 Clairton Underfire #11	595,630	4,461,920	120	69	700	37.27	1.220
12 Clairton Underfire #12	595,520	4,462,060	120	69	700	37.27	1.220
13 Clairton Underfire #13	595,380	4,461,930	120	69	700	37.74	1.310
14 Clairton Underfire #14	595,360	4,461,960	120	69	700	37.74	1.310
15 Clairton Underfire #15	595,210	4,462,110	120	69	700	37.74	1.310
16 Clairton Underfire #16	595,190	4,462,150	120	61	700	32.13	1.310
17 Clairton Underfire #17	595,110	4,462,240	120	61	700	32.13	1.310

TABLE 5-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
18 Clairton Underfire #18	595,020	4,462,330	120	76	700	32.300	1.460
19 Clairton Underfire #19	595,280	4,461,880	120	76	700	58.430	2.140
20 Clairton Underfire #20	595,250	4,461,910	120	76	700	58.430	2.140
21 Clairton Underfire #21	595,060	4,462,120	120	76	700	58.430	2.140
22 Clairton Underfire #22	595,030	4,462,160	120	76	700	58.430	2.140
23 Clairton Underfire #12A	595,500	4,462,080	120	69	700	35.870	1.520
24 Clairton B&W #1	595,000	4,462,470	2,062	50	455	92.570	1.370
25 Clairton CE #2	595,000	4,462,470	1,537	50	455	72.330	1.060
26 Clairton Benzene Boiler	594,870	4,462,400	723	52	16*	60.000*	--
27 Clairton Benzene Boiler	594,850	4,462,410	723	52	16*	60.000*	--
28 Clairton Blast Furnace	595,630	4,460,060	299	60	716	180.580	1.880
30 Clairton Claus Plant	595,810	4,461,550	1,413	46	561	18.030	.610
31 Irvin 3 and 4	593,220	4,465,600	683	55	646	54.550	1.790
32 Irvin 5 and 6	593,230	4,465,650	971	78	633	79.620	1.600
33 Irvin 7	593,250	4,465,710	756	30	483	33.400	.920
35 Elrama	592,000	4,456,200	0	83	416	198.950	2.150

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 5-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
36 Elrama	592,000	4,456,200	0	83	430	198.950	2.150
37 Elrama	592,000	4,456,200	0	83	430	229.450	2.150
38 Elrama	592,000	4,456,200	12,994	89	416	299.140	2.300
39 Mitchell	587,340	4,452,810	6,690	73	403	534.810	3.050
40 Mitchell	587,340	4,452,810	1,945	70	467	223.640	2.150
41 Mitchell	587,340	4,452,810	1,945	70	467	223.640	2.150
42 Mitchell	587,340	4,452,810	1,945	70	467	223.640	2.150
43 Irvin Reheat	593,250	4,465,600	150	52	10*	50.000*	--
44 Irvin Reheat	593,250	4,465,700	150	52	10*	50.000*	--
45 Irvin Reheat	593,250	4,465,650	150	52	10*	50.000*	--
46 Irvin Reheat	593,260	4,465,600	150	52	10*	50.000*	--
47 Irvin Reheat	593,260	4,465,650	150	52	10*	50.000*	--
48 Clairton Reheat	595,100	4,461,520	48	52	70*	70.000*	--
49 Clairton Reheat	595,100	4,461,530	48	52	70*	70.000*	--
50 Clairton Reheat	595,100	4,461,540	48	52	70*	70.000*	--
51 Clairton Reheat	595,100	4,461,500	48	52	70*	70.000*	--

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 5-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
52 Clairton Reheat	595,100	4,461,560	48	52	70*	70.000*	--
53 Clairton Reheat	595,100	4,461,570	48	52	70*	70.000*	--
54 Clairton Reheat	595,100	4,461,580	48	52	70*	70.000*	--
55 Pitron	593,850	4,464,500	39	75	600	88.000	2.000
60 Phillips Power Station	565,260	4,491,020	0	76	461	83.460	1.800
61 Phillips Power Station	565,260	4,491,020	0	76	461	83.460	1.800
62 Phillips Power Station	565,260	4,491,020	0	76	457	118.070	1.800
63 Phillips Power Station	565,260	4,491,020	0	76	457	118.070	1.800
64 Phillips Power Station	565,260	4,491,020	11,727	76	457	118.070	1.800
65 Phillips Power Station	565,260	4,491,020	0	49	430	167.850	2.300
66 Brunots Island Turbines	580,680	4,479,680	1,026	10	735	237.600	.900
67 Brunots Island Turbines	580,730	4,479,720	1,026	10	735	237.600	.900
68 Brunots Island Turbines	580,770	4,479,750	1,026	10	735	237.600	.900
69 12th Street Steam	585,200	4,477,600	1,956	82	604	108.260	2.000
70 Stanwix Street Steam	584,380	4,477,300	2,599	112	574	227.230	2.600
71 H. J. Heinz Co.	586,000	4,478,900	719	76	473	18.730	1.500

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 5-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
72 H. J. Heinz Co.	586,000	4,478,900	975	76	473	16.290	1.500
73 Westinghouse Electric	599,020	4,472,550	1,427	50	505	17.420	1.100
74 Westinghouse Electric	599,020	4,472,550	1,113	37	461	7.470	1.000
75 Bellefield Boilers	589,190	4,477,100	865	59	589	26.950	1.400
76 Bellefield Boilers	589,190	4,477,100	1,113	69	561	24.150	1.700
77 Pittsburgh Brewery	587,550	4,479,280	467	63	472	39.560	1.200
78 WABCO	594,400	4,475,550	580	27	569	19.310	.700
79 Duquesne N C Boilers	598,120	4,469,830	87	49	551	32.870	1.100
80 Duquesne Reheat	598,360	4,469,450	343	37	700	26.300	.900
81 E. T. N C Boilers	597,110	4,471,610	44	33	551	26.230	1.200
82 E. T. Soaking Pits	597,440	4,471,870	230	30	764	22.320	.800
83 Homestead N C Boilers	592,850	4,473,830	7	16	361	25.040	1.600
84 Homestead Process 1	593,400	4,473,870	445	32	50*	100.000*	--
85 Homestead Process 2	591,900	4,473,400	445	32	50*	100.000*	--
86 Homestead Process 3	593,150	4,473,850	445	32	50*	100.000*	--
87 Homestead #5 OH	592,350	4,473,750	1,515	38	532	153.930	2.000

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 5-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
88 National #1	597,400	4,467,330	752	46	590	39.250	1.300
89 National #2	597,450	4,467,330	752	46	590	39.250	1.300
90 National #3	597,500	4,467,330	752	46	590	39.250	1.300
91 National #4	597,550	4,467,330	752	46	590	39.250	1.300
92 National #5	597,600	4,467,330	752	46	590	39.250	1.300
93 Duquesne #15	598,120	4,469,830	475	49	551	32.870	1.100
94 Duquesne #17	598,120	4,469,830	475	49	551	32.870	1.100
95 E. T. #1	596,990	4,471,670	1,405	50	533	121.550	2.100
96 E. T. #2	596,990	4,471,670	1,405	50	533	121.550	2.100
97 E. T. #3	596,990	4,471,670	1,405	50	533	121.550	2.100
98 Homestead Carrie #3	594,120	4,474,020	1,964	43	561	200.320	2.400
99 Homestead Carrie #4	594,120	4,474,020	1,588	43	561	154.030	1.900
100 Mesta Machine Co.	590,920	4,471,980	511	61	511	7.360	.900
101 J & L By Products Boilers	589,250	4,473,900	387	24.4	616	6.150	.680
102 J & L Eliza Boilers	588,560	4,475,400	66	36.6	477	66.630	1.340
103 J & L South Side Boilers	588,030	4,475,280	1,602	35.7	477	26.650	1.220

TABLE 5-2 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/year)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
104 J & L Underfire #1	589,150	4,474,030	51	61	600	32.140	1.300
105 J & L Underfire #2	589,150	4,474,020	51	62.6	600	31.700	1.450
106 J & L Underfire #3	589,190	4,473,860	51	62.6	600	31.700	1.450
107 J & L Underfire #4	589,190	4,473,840	51	62.6	600	31.700	1.450
108 J & L Underfire #5	589,200	4,473,750	77	62.6	600	31.700	1.450
109 J & L Open Hearth	587,850	4,475,680	1,825	38	532	153.950	1.980
110 J & L Barmill #1	589,240	4,474,060	84	38.1	727	20.400	.840
111 J & L Barmill #2	589,260	4,474,150	40	38.1	727	24.900	1.070
112 J & L Stripmill	588,265	4,475,775	69	18.0	727	47.420	1.300
113 J & L Soaking Pits	587,780	4,475,470	95	48	727	4.850	.860
114 J & L Soaking Pits	587,800	4,475,550	88	34	727	2.920	.780
115 J & L Claus Plant	**589,190**	**4,474,000**	**694**	**46**	**977**	**24.63**	**.700**

1965 through 1971, found 1965 to represent the worst-case dilution conditions. Figure 5-3 shows the 1965 annual frequency distribution of wind direction at the Greater Pittsburgh Airport.

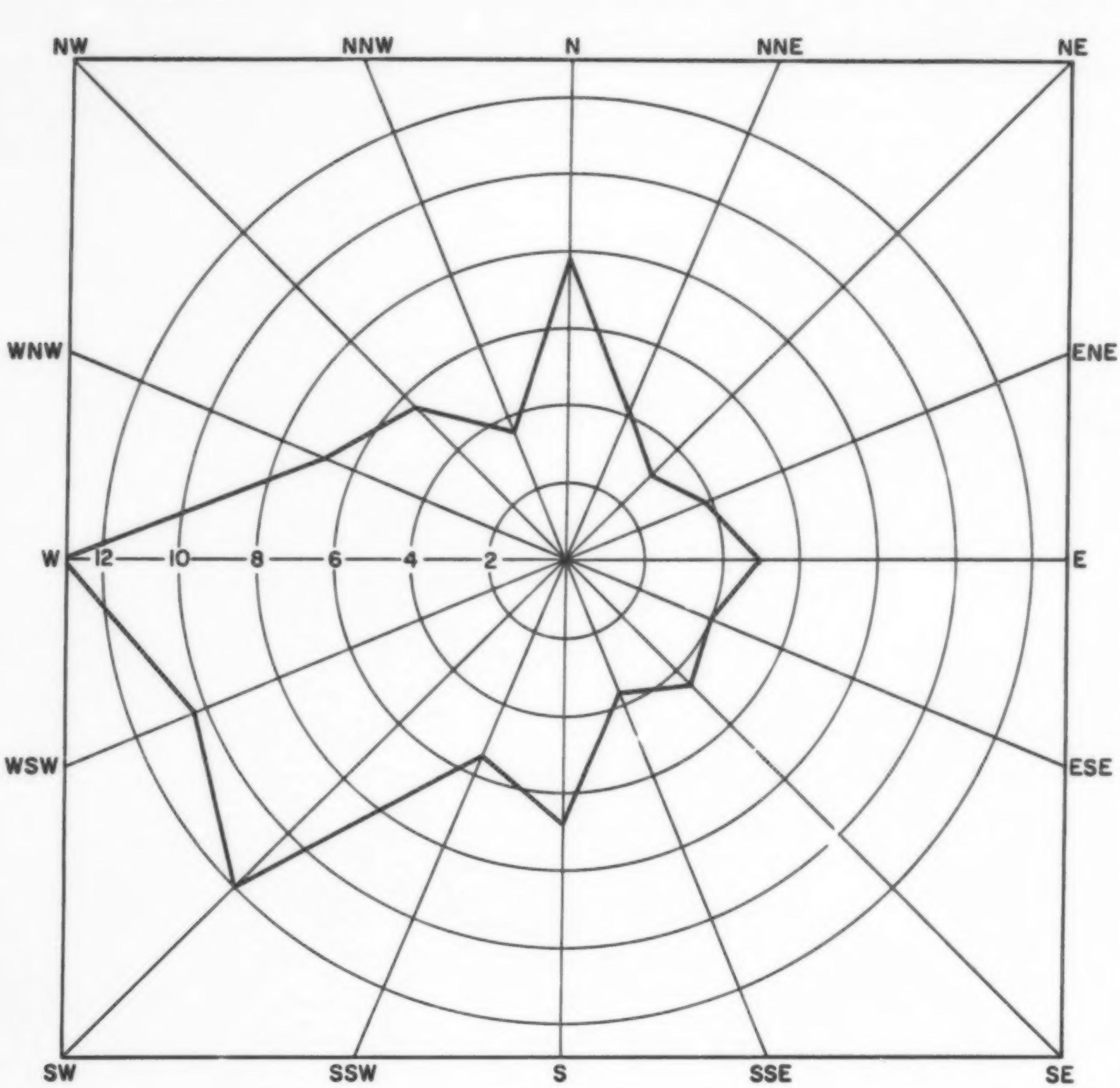


FIGURE 5-3. Annual frequency distribution of wind direction obtained from the 1965 surface observations at the Greater Pittsburgh Airport. Percent frequency scale is shown at left center.

SECTION 6

SHORT TERM HOURLY CONCENTRATIONS FOR 1973

To test the performance of the short-term model prior to using it for compliance-case calculations, model concentrations were calculated for three 24-hour periods during 1973 in which excessively high SO_2 concentration levels were observed at monitoring sites operated by the Allegheny County Bureau of Air Pollution Control. The three 24-hour periods and the monitor locations are:

- The 4 January 1973 Air Pollution Episode at Logans Ferry
- The 18 January 1973 Air Pollution Episode at Liberty Borough
- The 13 July 1973 Air Pollution Episode at Liberty Borough

The calculation procedures, the source and meteorological data and the results obtained for each of the three 24-hour cases are described below.

6.1 THE 4 JANUARY 1973 AIR POLLUTION EPISODE AT LOGANS FERRY

6.1.1 Background

During 1973, the 3-hour Secondary Air Quality Standard of 1300 micrograms per cubic meter was exceeded 8 times at the Logans Ferry SO_2 monitor and the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter was exceeded 20 times. Many of these high hourly ground-level SO_2 concentrations observed at the Logans Ferry monitor occurred during periods of neutral stability in combination with moderate to strong west-southwest winds. An episode of this type occurred on 4 January 1973 when strong west-southwest winds developed at about 0500 EST and persisted throughout the day. Two power plants, both located at a bearing of approximately 245 degrees from the Logans Ferry monitor, are the most likely major contributors to the observed high SO_2 concentrations. The West Penn power plant is located approximately 900 meters west-southwest of the monitor, while the Cheswick power plant is located at a distance of about 3100 meters west-southwest of the monitor. The ground elevation at both power plants, which corresponds to the elevation of the base of the stacks used in the calculations, is approximately 45 meters below the elevation of the Logans Ferry monitor.

The calculation procedures and the results of the 4 January 1973 short-term concentration calculations are described in Section 6.1.2. The source data and the meteorological data used in the calculations are discussed in Sections 6.1.3 and 6.1.4.

6.1.2 Calculation Procedures and Results

The short-term concentration model described in Section A.3 of Appendix A, including the adjustments for variations in terrain elevation described in Section A.5, was used with the source and meteorological data in Sections 6.1.3 and 6.1.4 to calculate hourly ground-level SO_2 concentrations at 256 grid points on the 10-kilometer by 10-kilometer grid shown in Figure 6-1. It is important to note that no attempt was made to calibrate the model through the use of scaling coefficients relating the calculated hourly concentrations at the monitor to the hourly concentrations observed at the monitor. The calculated hourly concentrations presented below were thus obtained directly from the emissions data and meteorological data and were in fact calculated without prior knowledge of the observations at the monitor.

Figure 6-2 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentration for 4 January 1973. The location of the Logans Ferry monitor is shown by the filled circle in Figure 6-2. Neglecting the ambient SO_2 background or the contributions of sources other than the West Penn and Cheswick power plants, the calculations indicate that the 24-hour Primary

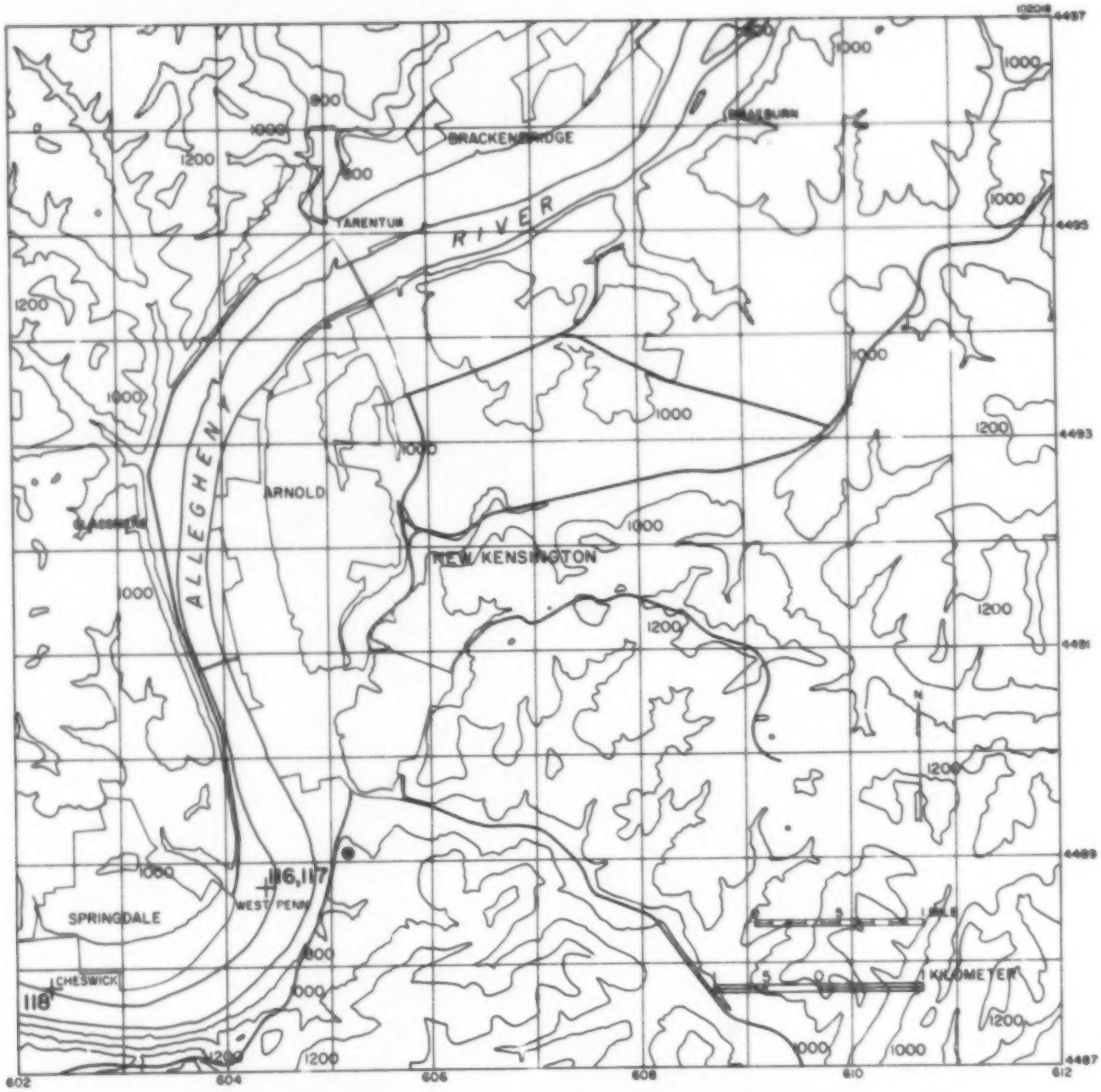
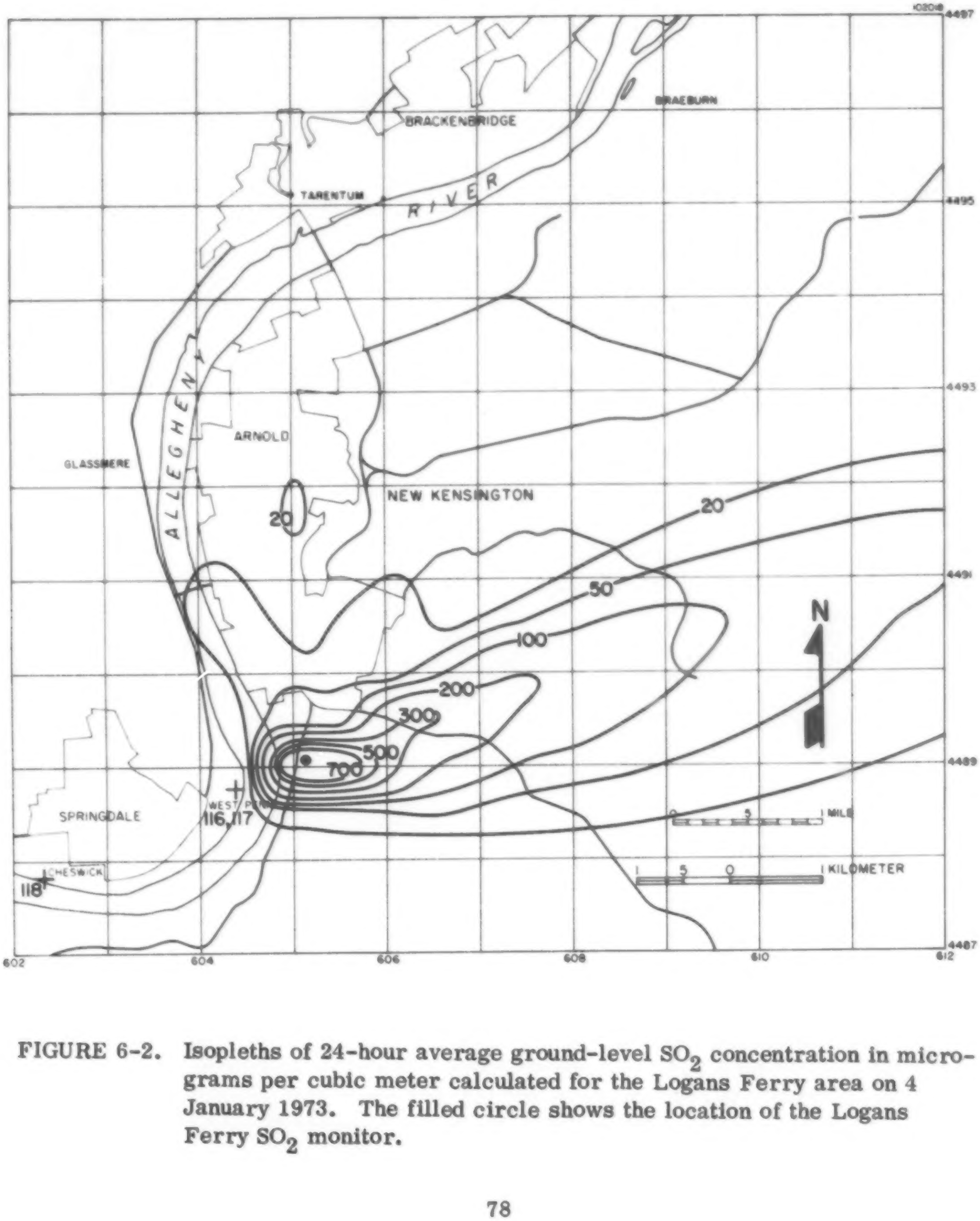

BRACKENRIDGE
BRAEBURN
TARENTUM
ALLEGHENY RIVER
ARNOLD
NEW KENSINGTON
SPRINGDALE
WEST PENN
CHESWICK
116,117
118
1 MILE
1 KILOMETER
N
800
1000
1200
602
604
606
608
610
612
4497
4495
4493
4491
4489
4487

FIGURE 6-1. Topographic map of the Springdale-Logans Ferry area. Elevations are in feet above mean sea level, and the contour interval is 200 feet. The + symbols show the locations of the West Penn Power Plant (Sources 116 and 117) and the Cheswick Power Plant (Sources 118). Filled circle shows the Logans Ferry SO_2 monitor.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BRAEBURN
BRACKENRIDGE
TARENTUM
RIVER
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ALLEGHENY
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ARNOLD
GLASSMERE
NEW KENSINGTON
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20
4491
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100
200
300
500
700
4489
WEST PT
116,117
SPRINGDALE
0 .5 1 MILE
CHESWICK
118
1 .5 0 1 KILOMETER
4487
602
604
606
608
610
612

FIGURE 6-2. Isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter calculated for the Logans Ferry area on 4 January 1973. The filled circle shows the location of the Logans Ferry SO_2 monitor.

Air Quality Standard of 365 micrograms per cubic meter was exceeded over an elongated area of approximately one square kilometer extending eastward from the Allegheny River opposite the West Penn power plant through the Logans Ferry SO_2 monitor.

Calculated and observed hourly SO_2 concentrations for the Logans Ferry monitor are given in Table 6-1. The calculated 24-hour average concentration of 979 micrograms per cubic meters for the combined sources is about 10 percent higher than the observed concentration. Additionally, the calculated maximum 3-hour concentration of 2207 micrograms per cubic meter is about 17 percent higher than the observed maximum 3-hour concentration of 1880 micrograms per cubic meter. Both the calculated and observed hourly concentrations show low values before 0500 EST, generally high values during the period 0600 to 1400 EST, and decreasing values after 1500 EST. The hour-by-hour correspondence of the calculated and observed concentrations is probably as good as can be expected because of the inherent coarseness of the hourly wind-direction data. As discussed in detail in Section 6.2.2, hourly mean wind directions used in the model calculations are based on airport surface observations which are reported only to the nearest 10 degrees. Because the hourly wind directions reported at the two Pittsburgh Airports frequently differ by 20 degrees or more, there is a minimum uncertainty of at least plus or minus 10 degrees in the hourly mean wind directions which precludes accurate predictions of the location of the stack plumes with respect to single grid points.

It should be noted that, although the SO_2 emissions from the Cheswick power plant on 4 January 1973 were nearly double the emission from the West Penn power plant, the Cheswick emissions account for only about 3 percent of the maximum short-term concentrations calculated for the Logans Ferry monitor. This result is consistent with the observation by Bloom and Smith (1974) that no increase in ambient SO_2 concentrations has been detected at the Logans Ferry monitor since the Cheswick power plant began operation in January 1971. The small contribution of the Cheswick emissions to the calculated concentrations at the Logans

TABLE 6-1

CALCULATED AND OBSERVED HOURLY GROUND-LEVEL SO_2 CONCENTRATIONS AT THE LOGANS FERRY MONITOR FOR 4 JANUARY 1973

Hour (EST)	Calculated Hourly SO_2 Concentration ($\mu g/m^3$)			Observed Hourly Concentration ($\mu g/m^3$)
	West Penn	Cheswick	Combined Sources	
01	0	0	0	13
02	0	0	0	26
03	0	0	0	26
04	0	0	0	21
05	3167	108	3275	2028
06	505	13	518	1732*
07	489	14	503	1828*
08	1971	78*	2049	2080*
09	2083*	74*	2157*	1103
10	2147*	72*	2219*	1517
11	2174*	71	2245*	1378
12	2064	63	2127	865
13	2049	75	2124	1378
14	2199	67	2266	865
15	410	10	420	1279
16	22	0	22	977
17	44	0	44	1344
18	1	0	1	1069
19	44	0	44	519
20	1670	57	1727	144
21	795	48	843	34
22	857	30	887	430
23	21	1	22	886
24	0	0	0	423
24-Hour Average	946	33	979	891
*3-Hour Maximum	2135	75	2207	1880

Ferry monitor is principally due to the fact that the Cheswick stack is about 3.5 times higher than the West Penn stacks. The calculated maximum hourly and 24-hour average ground-level SO_2 concentrations resulting from the Cheswick emissions alone are 162 and 65 micrograms per cubic meter, respectively. Both of these maximums occur about 1000 meters east-northeast of the Logans Ferry monitor.

6.1.3 Source Data

Table 6-2 lists the sources, source locations, SO_2 emission rates and stack parameters that were used to calculate hourly ground-level SO_2 concentrations for the 4 January 1973 air pollution episode at Logans Ferry. The source and emissions data given in Table 6-2 were supplied by the Allegheny County Bureau of Air Pollution Control. The locations of the West Penn power plant (Sources 116 and 117) and the Cheswick power plant (Source 118) are shown in Figures 6-1 and 6-2. The filled circles in these figures show the location of the Logans Ferry SO_2 monitor. As mentioned above, the ambient SO_2 background and the contributions of sources other than the West Penn and Cheswick power plants were not included in the model calculations for 4 January 1973.

6.1.4 Meteorological Data

Table 6-3 lists, for each hour, the wind direction, surface wind speed, mixing depth, ambient air temperature and vertical potential temperature gradient used in the calculations for the 4 January 1973 air pollution episode at Logans Ferry. The hourly wind directions and speeds are arithmetic means of the concurrent observations at the Greater Pittsburgh Airport and Allegheny County Airport. Rawinsonde data taken at the Greater Pittsburgh Airport at 1900 EST on 3 January, 0700 and 1900 EST on 4 January and 0700 EST on 5 January were used to estimate mixing

TABLE 6-2

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE 1-HOUR, 3-HOUR AND 24-HOUR GROUND-LEVEL SO_2 CONCENTRATIONS FOR THE 4 JANUARY 1973 AIR POLLUTION EPISODE AT LOGANS FERRY

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
116 West Penn	604,380	4,488,740	30.3	67.1	472	160.98	2.60
117 West Penn	604,380	4,488,740	30.3	62.5	444	162.14	1.85
118 Cheswick	602,330	4,487,800	120.0	229.0	411	881.46	3.20

TABLE 6-3

METEOROLOGICAL INPUT PARAMETERS FOR 4 JANUARY 1973

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	170	5.4	953	283	0	D
02	190	6.7	1068	284	0	D
03	210	10.0	1184	285	0	D
04	220	9.8	1299	285	0	D
05	245	8.2	1415	283	0	D
06	255	9.3	1530	282	0	D
07	255	9.8	1645	280	0	D
08	250	10.3	1598	280	0	D
09	250	9.0	1551	280	0	D
10	250	8.5	1504	279	0	D
11	250	8.2	1457	279	0	D
12	250	7.2	1410	279	0	D
13	250	9.3	1363	279	0	D
14	250	7.7	1316	278	0	D
15	255	6.7	1269	278	0	D
16	260	6.2	1221	277	0	D
17	260	7.7	1174	276	0	D
18	265	6.7	1127	276	0	D
19	260	7.7	1080	275	0	D
20	250	6.7	1033	275	0	D
21	250	5.9	986	275	0	D
22	240	6.2	939	275	0	D
23	260	6.2	892	274	0	D
24	270	5.9	845	274	0	D

depths for the four observation times; mixing depths for intermediate hours were obtained by linear interpolation. The two Greater Pittsburgh Airport soundings on 4 January, as well as the 4 January 1200 EST sounding taken at the downtown Pittsburgh EMSU station, all showed a deep surface mixing layer with a near-adiabatic thermal stratification. Consequently, the vertical potential temperature gradient was set equal to zero for all hours of 4 January 1973. The ambient air temperatures listed in Table 6-2 are those observed at the Greater Pittsburgh Airport. Wind speeds from the four Greater Pittsburgh Airport soundings were averaged and a logarithmic least-squares regression curve was fitted to the data to obtain a value for the wind-profile exponent p of 0.17. Details of the regression technique are given in Section 3.3. Following the Turner (1964) criteria, the strong surface wind speeds and overcast clouds below 3000 feet require the Pasquill stability category D be assigned to all hours of 4 January 1973. The hourly lateral and vertical turbulent intensities were therefore set equal to the urban values for Pasquill stability category D of 0.1051 and 0.0735 radians, respectively (see Table 3-5).

6.2 THE 18 JANUARY 1973 AIR POLLUTION EPISODE AT LIBERTY BOROUGH

6.2.1 Background

During 1973, the 3-hour Secondary Air Quality Standard of 1300 micrograms per cubic meter was exceeded 3 times at the Liberty Borough SO_2 monitor. Similarly the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter was exceeded 16 times. The observed high SO_2 concentrations at the Liberty Borough monitor typically occur during periods of persistent south-southwest winds. These conditions occurred in combination with shallow mixing depths on 18 January 1973. The Clairton Coke Works, which is located approximately 2.4 kilometers south-southwest of the Liberty Borough SO_2 monitor, is a major source of SO_2 emissions.

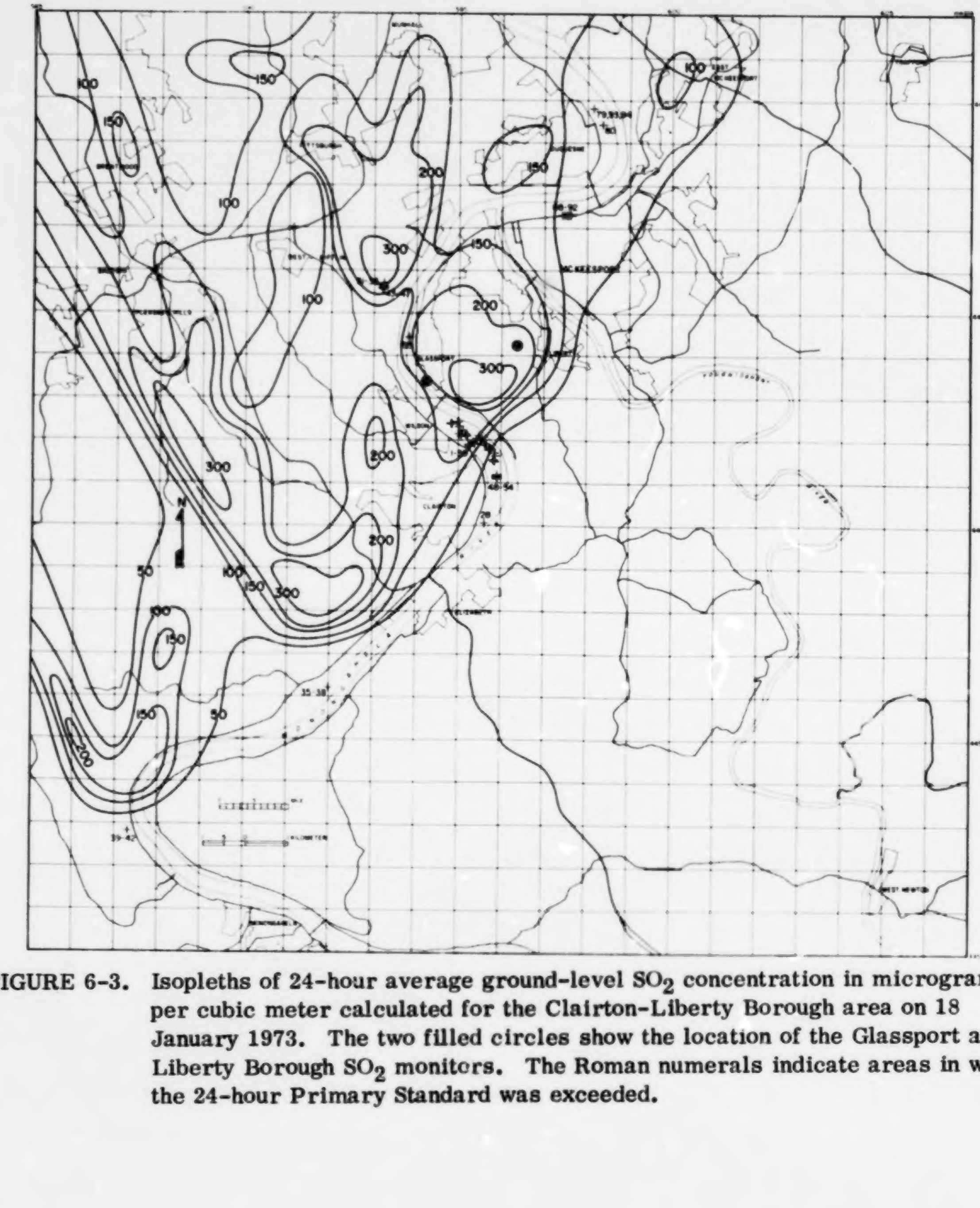
Other major sources include two large electrical generating plants, Mitchell and Elrama, which are respectively located 14.5 and 8.9 kilometers south-southwest of the Liberty Borough monitor.

Section 6.2.2 describes the calculation procedures and the results of the 18 January 1973 short-term concentration calculations. Emissions data for the major sources on 18 January 1973 are given in Section 6.2.3 and the meteorological inputs used in the 18 January 1973 calculations are described in Section 6.2.4.

6.2.2 Calculation Procedures and Results

The source and meteorological inputs in Sections 6.2.3 and 6.2.4 were used with the short-term concentration model described in Section A.3 of Appendix A to calculate hourly ground-level SO_2 concentrations for 649 grid points on a 21-kilometer by 28-kilometer grid that includes most of the area shown in Figure 6-3. A topographic map of the grid area is presented in Figure 4-1. Variations in terrain height over the calculation grid were considered in the calculations following the procedures outline in Section A.5 of Appendix A. It should be noted that calculated concentrations were not adjusted through the use of any model calibration constants which are sometimes employed to obtain agreement between observed and calculated concentrations at monitor locations. The calculated concentrations for 18 January 1973 were thus obtained directly from the emissions data and meteorological inputs in Sections 6.2.3 and 6.2.4.

Figure 6-3 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentrations for 18 January 1973. According to the calculations, which do not include background SO_2 nor contributions from sources other than those listed in Table 6-6, the 24-hour Primary Air Quality Standard was exceeded in the three areas designated by Roman numerals I, II and III in Figure 6-3. In Area I, which is located approximately 2.2 kilometers north of the Elrama power plant, the calculated maximum 24-hour concentration is 457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MCKEESPORT
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CLAIRTON
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N
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100
150
300
ELIZABETH
100
150
35-38
150
50
200
39-42
KILOMETER
WEST NEWTON

FIGURE 6-3. Isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter calculated for the Clairton-Liberty Borough area on 18 January 1973. The two filled circles show the location of the Glassport and Liberty Borough SO_2 monitors. The Roman numerals indicate areas in which the 24-hour Primary Standard was exceeded.

micrograms per cubic meter of which the Elrama power plant contributed 89 percent and the Mitchell power plant contributed the remaining 11 percent. In Area II, which is located approximately 0.5 kilometers north of the Irvin plant, the calculated maximum 24-hour concentration is 579 micrograms per cubic meter of which the Irvin plant contributed 54 percent, the Clairton Coke works 27 percent, the Elrama power plant 16 percent and the Mitchell power plant 3 percent. In Area III, which is located approximately 1.2 kilometers north of the Clairton Coke Works, the calculated maximum 24-hour concentration is 472 micrograms per cubic meter of which the Clairton Coke Works contributed 88 percent and the Elrama power plant contributed 11 percent.

The only air quality data available for comparison with the calculated concentrations consists of observations of hourly SO_2 concentrations from the Glassport and Liberty Borough monitors. As shown in Figure 6-3, the Glassport SO_2 monitor is located approximately 1.5 kilometers north-northwest of the Clairton Coke Works and the Liberty Borough monitor is located approximately 2.4 kilometers north-northeast of the Clairton Coke Works. Table 6-4 lists the calculated 24-hour average SO_2 concentrations at the two monitors for the combined sources and for each source and major source complex independently. Of the 24-hour average concentration of 189 micrograms per cubic meter calculated for the Glassport monitor, 50 percent is contributed by the Clairton Coke Works, 45 percent by the Elrama power plant and 5 percent by the Mitchell power plant. Similarly, for the Liberty Borough monitor, of the calculated 24-hour average concentration from the combined sources of 268 micrograms per cubic meter, 70 percent is due to the Clairton Coke Works, 27 percent is due to the Elrama power plant and 3 percent is do to the Mitchell power plant.

Table 6-5 presents the calculated and observed hourly concentrations at the two monitors as well as the 24-hour average and 3-hour maximum concentrations. The generally poor hour-by-hour correspondence at both monitors between calculated and observed concentrations can be shown to be an inevitable consequence

TABLE 6-4

CALCULATED 24-HOUR AVERAGE GROUND-LEVEL SO_2 CONCENTRATIONS AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITORS ON 18 JANUARY 1973*

Source	24-Hour Average Concentration ($\mu g/m^3$)			
	Glassport Monitor		Liberty Borough Monitor	
Clairton				
Coke Ovens	41 (22%)		110 (41%)	
Power Boilers	30 (16%)		8 (3%)	
Reheat and Blast Furnaces	19 (10%)		9 (3%)	
Claus Plant	3 (2%)		62 (23%)	
All Sources		93 (50%)		188 (70%)
Irvin				
Process	0 (0%)		0 (0%)	
Reheat	0 (0%)		0 (0%)	
All Sources		0 (0%)		0 (0%)
Elrama		84 (45%)		72 (27%)
Mitchell		9 (5%)		8 (3%)
Pitron		0 (0%)		0 (0%)
Combined Sources		186 (100%)		268 (100%)

*Numbers enclosed in parentheses show the percentage of the total calculated concentration allocated to each source.

of the limitations of the airport surface wind-direction data from which the hourly mean wind directions used as input to the model calculations are directly obtained. As pointed out above in the discussion of the results of the concentration calculations for the 4 January 1975 episode at Logans Ferry (see Section 6.1), the hourly airport surface wind directions are reported only to the nearest 10 degrees. The accurate positioning of stack plume trajectories with respect to fixed grid points requires that the hourly mean wind direction be known within a few degrees. Figures 6-4 and 6-5 show the effect of a change of 10 degrees in the mean wind direction on the positions of the plume envelopes from the Elrama and Mitchell power plants with respect to the Glassport and Liberty Borough monitors for Pasquill stability category D. From Figure 6-4 it can be seen that when the hourly mean wind direction is 210 degrees, the Elrama plume is almost directly over the Liberty Borough monitor and has no effect on the Glassport monitor. Also, the Mitchell plume is above the Glassport monitor but does not affect the Liberty Borough monitor. Figure 6-5 shows that a shift of 10 degrees in the hourly mean wind direction to 220 degrees places the western edge of the Elrama plume about 0.5 kilometers east of the Liberty Borough monitor. Similarly, the central portion of the Mitchell plume is about directly above the Liberty Borough monitor and the Glassport monitor is very close to the western edge of the Mitchell plume. Figures 6-6 and 6-7 show the envelope of the stack emissions from the Clairton Coke Works for hourly mean wind directions respectively of 180 degrees and 230 degrees. According to the figures, the Glassport monitor is outside the Clairton plume envelope in both cases; Clairton emissions that reach the Glassport monitor for hourly mean wind directions between 180 and 230 degrees should therefore be small and presumably consist of low-level fugitive emissions and some of the stack emissions that do not rise above the valley sides, but follow the valley contours toward Glassport. The figures also show that the Clairton plume will affect the Liberty Borough monitor for all wind directions between 180 degrees and 230 degrees, with the maximum impact confined to wind directions from about 190 degrees to 220 degrees. It is important to note that wind directions in this sector are also responsible for transporting the Mitchell and

TABLE 6-5

CALCULATED AND OBSERVED HOURLY GROUND-LEVEL SO_2 CONCENTRATIONS AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITORS ON 18 JANUARY 1973

Hour (EST)	Glassport Monitor		Liberty Borough Monitor	
	Calculated Concentration ($\mu g/m^3$)	Observed Concentration ($\mu g/m^3$)	Calculated Concentration ($\mu g/m^3$)	Observed Concentration ($\mu g/m^3$)
01	70	177	1440	952
02	753	151	401	941
03	0	133	1	939
04	63	135	627*	998
05	97	117	896*	1284*
06	64	130	627*	1240*
07	455	135	377	1391*
08	55	151	549	918
09	122	166	410	907
10	10	216*	2	692
11	212	278*	216	715
12	17	406*	119	455
13	16	120	122	299
14	15	153	124	333
15	245	192	207	153
16	33	114	315	140
17	0	143	0	117
18	392	104	0	148
19	490	62	0	224
20	129	88	0	250
21	149*	94	0	452
22	494*	96	0	1110
23	483*	117	0	562
24	92	187	0	291
24-Hour Average	186	153	268	647
*3-Hour Maximum	375	300	717	1305

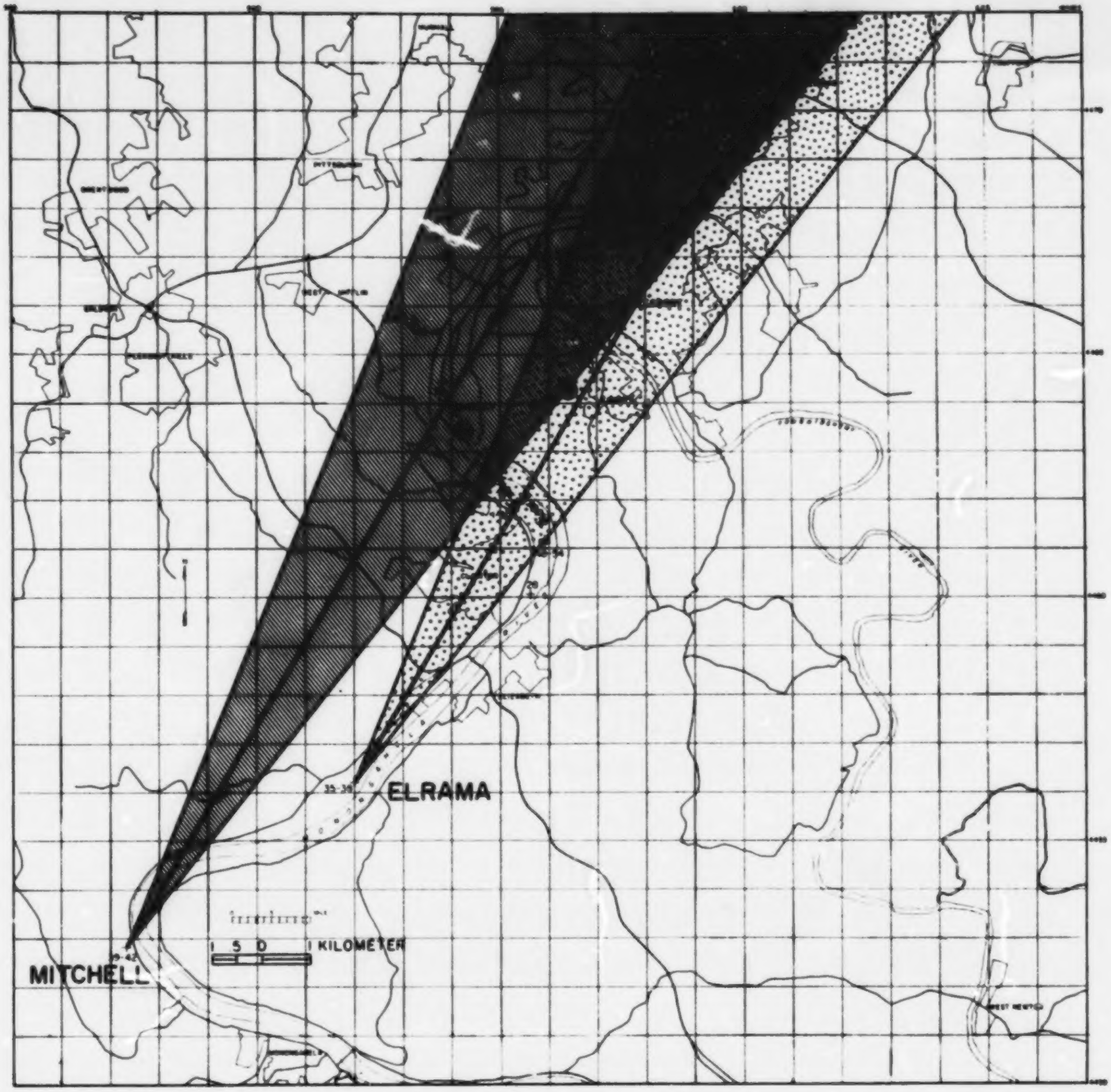
ELRAMA
MITCHELL
1 .5 0 1 KILOMETER

FIGURE 6-4. Map of the Calirton area showing Mitchell and Elrama plume dimensions ($\pm$ 2.15 σ_y) for Pasquill stability category D and winds from 210°. The Glassport and Liberty Borough SO_2 monitors are indicated by the filled circles.

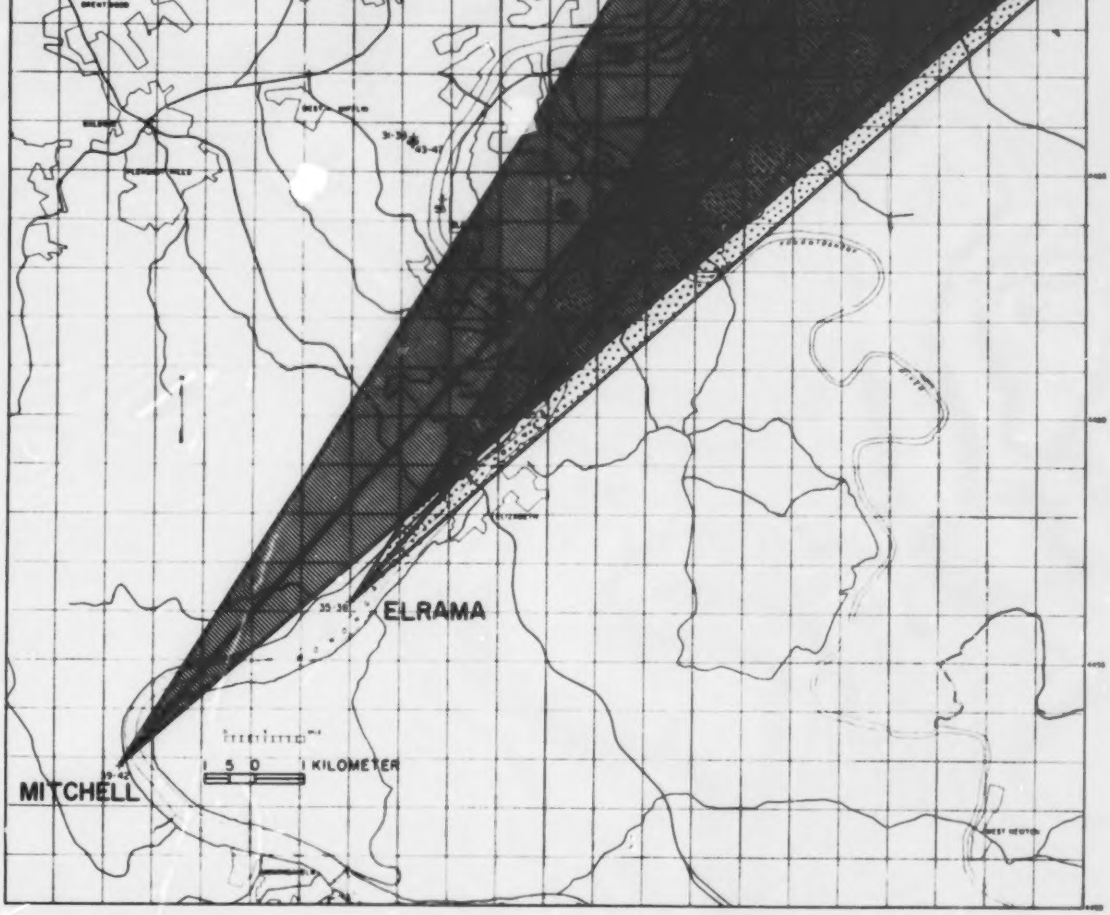
ELRAMA
35-36
MITCHELL
39-42
1 .5 0 1 KILOMETER

FIGURE 6-5. Map of the Clairton area showing Mitchell and Elrama plume dimensions ($\pm$ 2.15 σ_y) for Pasquill stability category D and winds from 220°. The Glassport and Liberty Borough SO_2 monitors are indicated by the filled circles.

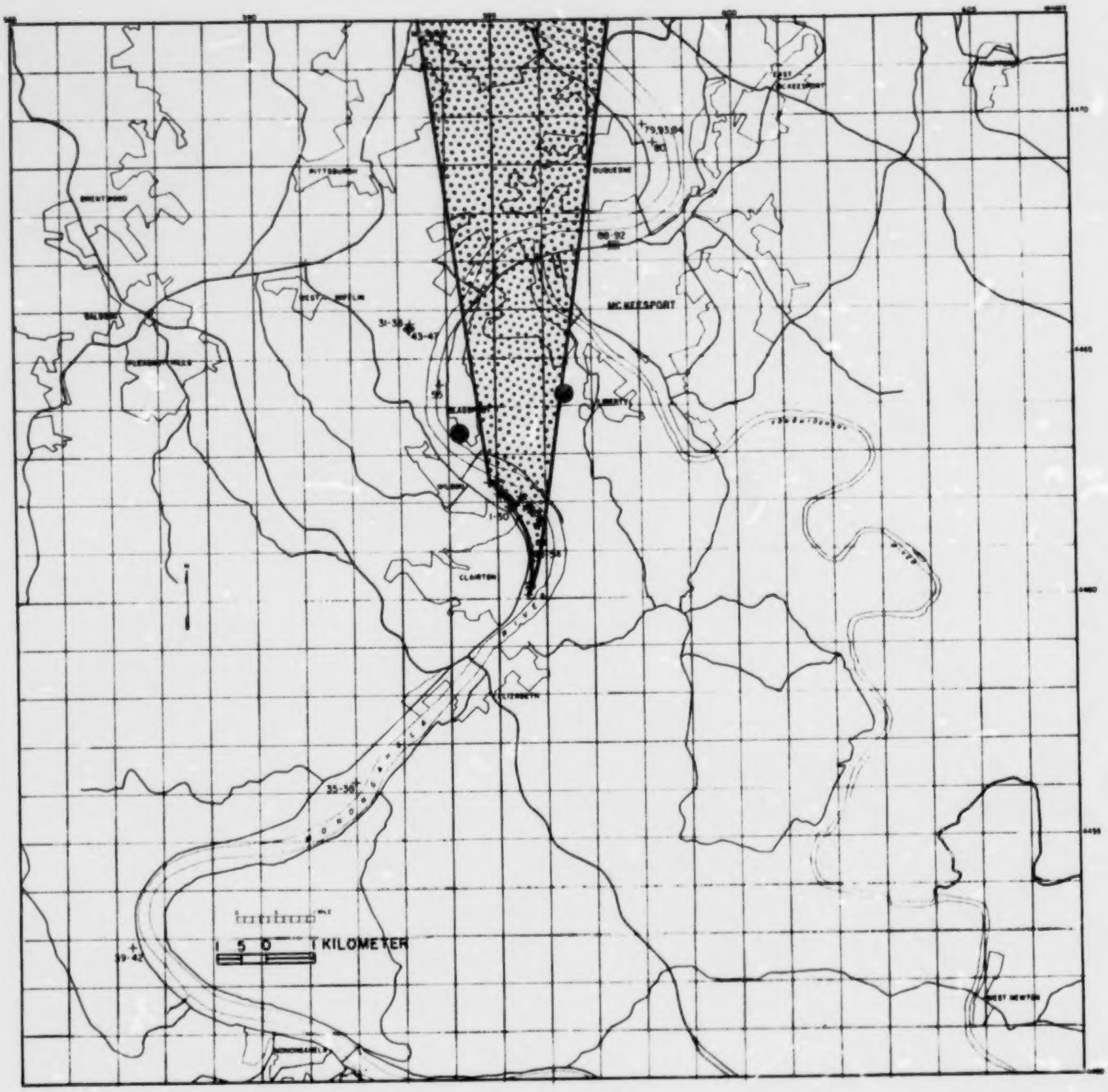
BRENTWOOD
PITTSBURGH
DUQUESNE
MC KEESPORT
WEST MIFFLIN
31-38
43-47
79,93,94
80
86-92
LIBERTY
1-30
CLAIRTON
ELIZABETH
35-36
39-42
1 5 0 1 KILOMETER
WEST NEWTON

FIGURE 6-6. Approximate area affected by emissions from the Clairton Coke Works for Pasquill stability category D and winds from 180° The filled circles show the locations of the Glassport and Liberty Borough SO_2 monitors.

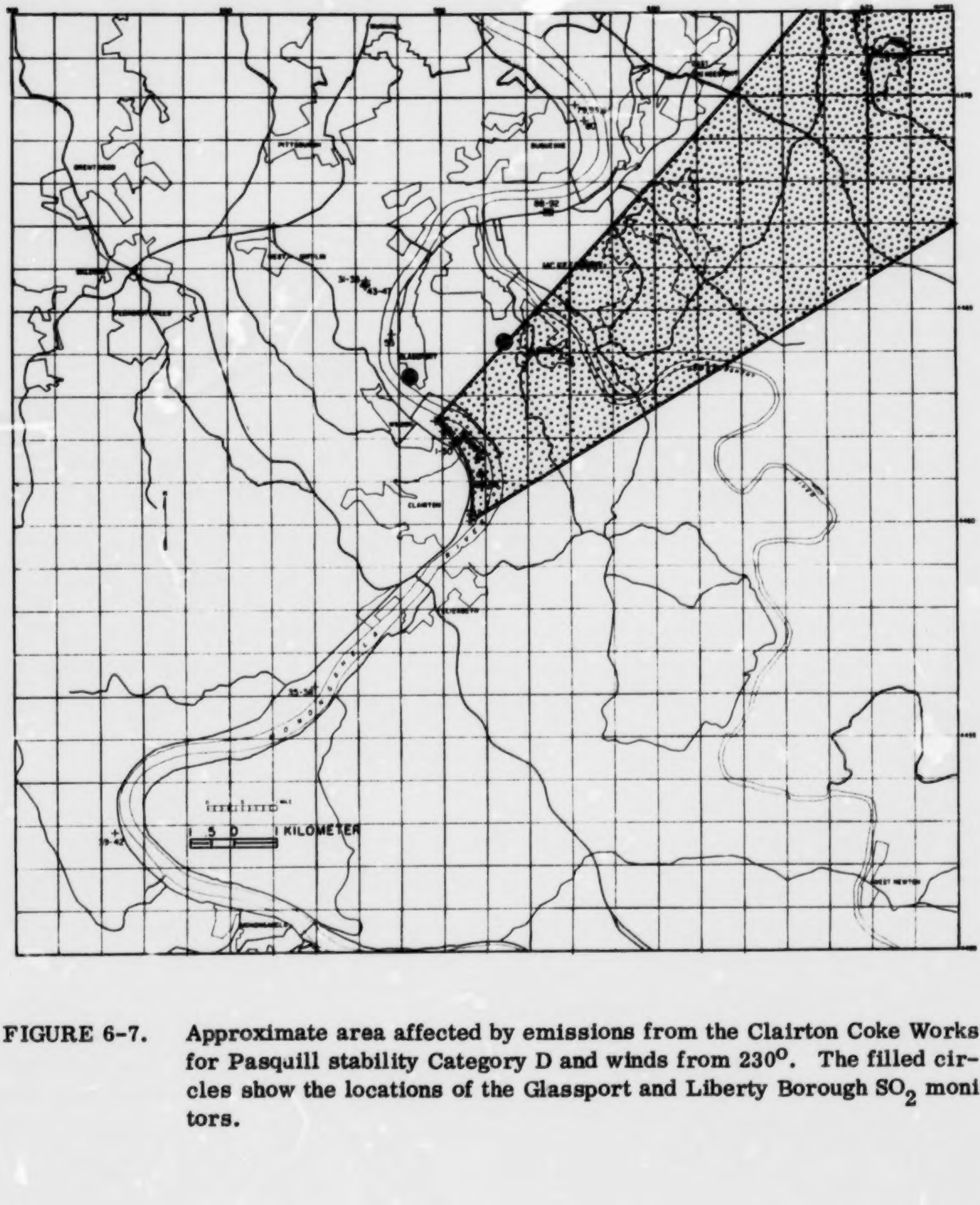
PITTSBURGH
31-39
43-47
CLAIRTON
1 .5 0 1 KILOMETER

FIGURE 6-7. Approximate area affected by emissions from the Clairton Coke Works for Pasquill stability Category D and winds from 230°. The filled circles show the locations of the Glassport and Liberty Borough SO_2 monitors.

Elrama plumes to the Liberty Borough monitor (a wind direction of about 210 degrees places the axis of the Elrama plume above the Liberty Borough monitor and a direction of about 220 degrees places the axis of the Mitchell plume above the Liberty Borough monitor).

Inspection of the hourly mean wind directions used in the 18 January 1973 model calculations, which are given below in Table 6-7, shows that they vary from 170 degrees to 220 degrees during the period 0100 to 1600 EST; during the period 1700 to 2400 EST, the hourly mean wind directions vary from 150 to 170 degrees. Therefore, in the model calculations, emissions from the Clairton Coke Works, Elrama and Mitchell cannot affect the Liberty Borough monitor after 1600 EST. As shown in Table 6-5, the observed hourly concentrations at the Liberty Borough monitor do reach their lowest values after 1400 EST, but never go below 117 micrograms per cubic meter. Very high concentrations were also observed at 2100, 2200 and 2300 EST. For these latter hours, if we assume the monitor observations are correct, there must be deficiencies in the wind-direction data and/or the emissions data. Deficiencies in the wind-direction data are to be expected since the only measurements available are the routine hourly surface observations at the two airports. In the model calculations, it is assumed that these surface wind directions are representative of the mean wind directions in the mixing layer which typically extends to heights of several hundred meters or more above the surface. Concurrent hourly wind directions measured at the Greater Pittsburgh Airport and at Allegheny County Airport differed by 20 or more degrees for 13 of the 24 hours on 18 January 1973. On this basis, a minimum uncertainty of 20 degrees in the hourly mean wind directions over the calculation grid appears to be likely. It should also be noted that the airport wind directions are 5 - minute averages rather than hourly averages as required by the short-term models. Thus, neglecting the additional complications of vertical wind-direction shear in the mixing layer, the hourly airport wind direction is clearly inadequate for making accurate model calculations of hourly concentrations at specific grid points. Additionally, it is likely that there were significant hour-to-hour variations in emissions rates that are not reflected in the emissions data used in the model calculations.

For the reasons given above, we believe the poor hour-by-hour correspondence between claculated and observed hourly concentration is attributable both to deficiencies in the wind-direction data and in the emissions data. As might be expected, the averaging process tends to remove some of the effects of these deficiencies for averaging times of 12 to 24 hours. The 3-hour maximum concentration calculated at the Glassport monitor is about 25 percent higher than the observed concentration and the 24-hour average concentration is about 22 percent higher than the observed value. At the Liberty Borough monitor, the calculated 24-hour average and 3-hour maximum concentrations are considerably lower than the observed concentrations. However, it would be possible to obtain a very close agreement between the calculated and observed values simply by making a few adjustments in the hourly mean wind directions, using the observed hourly concentrations as a guide. For example, our analysis of the calculated values shows that the maximum hourly concentration at the Liberty Borough monitor on 18 January 1973 that could be produced by emissions from the Clairton Coke Works is probably less than 700 micrograms per cubic meter (see the calculated hourly values in Table 6-5 for 0400 EST and 0600 EST where the model wind direction is 190 degrees). We conclude that observed hourly concentrations significantly larger than 700 micrograms per cubic meter are principally caused by the Elrama plume. Emissions from Elrama account for 71 percent of the maximum hourly concentration calculated for the Liberty Borough monitor (1440 micrograms per cubic meter). This calculated maximum hourly concentration, which compares favorably with the maximum observed hourly concentration of 1391 micrograms per cubic meter, occurs with the 210-degree wind direction which places the Elrama plume almost directly above the Liberty Borough monitor.

6.2.3 Source Data

Table 6-6 lists the sources, source locations, SO_2 emission rates and stack parameters that were used to calculate short-term ground-level SO_2 concentrations for the 18 January 1973 air pollution episode at Liberty Borough. The source and emissions data given in Table 6-6 were obtained from the Allegheny County Bureau of

TABLE 6-6

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE SHORT-TERM SO_2 CONCENTRATIONS FOR THE 18 JANUARY 1973 AIR POLLUTION EPISODE AT LIBERTY BOROUGH

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
1 Clairton Underfire #1	595, 860	4, 461, 520	1. 16	69	700	37. 27	1. 220
2 Clairton Underfire #2	595, 830	4, 461, 540	1. 16	69	700	37. 27	1. 220
3 Clairton Underfire #3	595, 730	4, 461, 780	1. 16	69	700	37. 27	1. 220
7 Clairton Underfire #7	595, 880	4, 461, 650	1. 16	65	700	35. 87	1. 270
8 Clairton Underfire #8	595, 870	4, 461, 680	1. 16	65	700	35. 87	1. 270
9 Clairton Underfire #9	595, 750	4, 461, 810	1. 16	65	700	35. 87	1. 270
10 Clairton Underfire #10	595, 660	4, 461, 900	1. 16	69	700	37. 27	1. 220
11 Clairton Underfire #11	595, 630	4, 461, 920	1. 16	69	700	37. 27	1. 220
12 Clairton Underfire #12	595, 520	4, 462, 060	1. 16	69	700	37. 27	1. 220
13 Clairton Underfire #13	595, 380	4, 461, 930	1. 16	69	700	37. 74	1. 310
14 Clairton Underfire #14	595, 360	4, 461, 960	1. 16	69	700	37. 74	1. 310
15 Clairton Underfire #15	595, 210	4, 462, 110	1. 16	69	700	37. 74	1. 310
16 Clairton Underfire #16	595, 190	4, 462, 150	1. 16	61	700	32. 13	1. 310
17 Clairton Underfire #17	595, 110	4, 462, 240	1. 16	61	700	32. 13	1. 310

TABLE 6-6 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
18 Clairton Underfire #18	595,020	4,462,330	1.16	76	700	32.300	1.460
19 Clairton Underfire #19	595,280	4,461,880	1.16	76	700	58.430	2.140
20 Clairton Underfire #20	595,250	4,461,910	1.16	76	700	58.430	2.140
21 Clairton Underfire #21	595,060	4,462,120	1.16	76	700	58.430	2.140
22 Clairton Underfire #22	595,030	4,462,160	1.16	76	700	58.430	2.140
23 Clairton Underfire #12A	595,500	4,462,080	1.16	69	700	35.870	1.520
24 Clairton B&W #1	595,000	4,462,470	2.50	50	455	92.570	1.370
25 Clairton CE #2	595,000	4,462,470	0	50	455	72.330	1.060
26 Clairton Benzene Boiler	594,870	4,462,400	.5	52	16*	60.000*	--
27 Clairton Benzene Boiler	594,850	4,462,410	.5	52	16*	60.000*	--
28 Clairton Blast Furnace	595,630	4,460,060	.83	60	716	180.580	1.880
30 Clairton Claus Plant	595,810	4,461,550	11.0	46	561	18.030	.610
31 Irvin 3 and 4	593,220	4,465,600	2.26	55	646	54.550	1.790
32 Irvin 5 and 6	593,230	4,465,650	3.38	78	633	79.620	1.600
33 Irvin 7	593,250	4,465,710	2.57	30	483	33.400	.920
35 Elrama	592,000	4,456,200	32.	83	416	198.950	2.150

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 6-6 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
36 Elrama	592,000	4,456,200	34.	83	430	198.950	2.150
37 Elrama	592,000	4,456,200	0.	83	430	229.450	2.150
38 Elrama	592,000	4,456,200	57.	89	416	299.140	2.300
39 Mitchell	587,340	4,452,810	0	73	403	534.810	3.050
40 Mitchell	587,340	4,452,810	20.18	70	467	223.640	2.150
41 Mitchell	587,340	4,452,810	20.18	70	467	223.640	2.150
42 Mitchell	587,340	4,452,810	20.18	70	467	223,640	2.150
43 Irvin Reheat	593,250	4,465,600	1.0	52	10*	50.000*	--
44 Irvin Reheat	593,250	4,465,700	1.0	52	10*	50.000*	--
45 Irvin Reheat	593,250	4,465,650	1.0	52	10*	50.000*	--
46 Irvin Reheat	593,260	4,465,600	1.0	52	10*	50.000*	--
47 Irvin Reheat	593,260	4,465,650	1.0	52	10*	50.000*	--
48 Clairton Reheat	595,100	4,461,520	.36	52	70*	70.000*	--
49 Clairton Reheat	595,100	4,461,530	.36	52	70*	70.000*	--
50 Clairton Reheat	595,100	4,461,540	.36	52	70*	70.000*	--
51 Clairton Reheat	595,100	4,461,500	.36	52	70*	70.000*	--

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 6-6 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
52 Clairton Reheat	595,100	4,461,560	.36	52	70*	70.000*	--
53 Clairton Reheat	595,100	4,461,570	.36	52	70*	70.000*	--
54 Clairton Reheat	595,100	4,461,580	.36	52	70*	70.000*	--
55 Pittron	593,850	4,464,500	.11	75	600	88.000	2.000

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

Air Pollution Control and a paper by Smith (1973). The locations of the sources are shown in Figure 6-3 and on a topographic map of the Clairton-Liberty Borough area in Figure 4-1 of Section 4. It should be noted that the calculations for 18 January 1973 do not include the effects of the ambient SO_2 background or the other SO_2 sources in the Pittsburgh area.

6.2.4 Meteorological Data

Table 6-7 lists, for each hour, the mean wind direction, surface wind speed, mixing depth, ambient air temperature and vertical potential temperature gradient used in the calculations for the 18 January 1973 air pollution episode at Liberty Borough. The hourly wind directions and speeds are arithmetic means of concurrent pairs of observations at the Greater Pittsburgh Airport and Allegheny County Airport, and the ambient air temperatures are the temperatures measured at the Greater Pittsburgh Airport. The mixing depths in Table 6-7 were assigned on the basis of rawinsonde data from the Greater Pittsburgh Airport for 1900 EST on 17 January, 0700 and 1900 EST on 18 January and 0700 EST on 19 January. The nighttime and early morning mixing depth of 125 meters was estimated from the strength and vertical extent of the ground inversion, and from the results of the analysis of Pittsburgh mixing depths summarized in Table 3-6. The four Greater Pittsburgh Airport soundings and the 18 January 1200 EST sounding taken at the downtown Pittsburgh EMSU station provided five observations of the vertical potential temperature gradient. Potential temperature gradients for the remaining hours of 18 January 1973 were estimated by linear interpolation.

Following the Turner (1964) procedures for determining the Pasquill stability category, the average wind speeds listed in Table 6-7 and the cloud cover observations at the Greater Pittsburgh Airport were used to determine the stability category for each hour. As shown by the right-hand column of Table 6-7, there were 14 hours of Pasquill stability category D, 8 hours of Pasquill stability category E and 2 hours of Pasquill stability category C on 18 January 1973. The hourly lateral and vertical turbulent intensities were set equal to the appropriate urban values given in Table 3-5.

TABLE 6-7

METEOROLOGICAL INPUT PARAMETERS FOR 18 JANUARY 1973

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	210	3.6	125	279	0.015	E
02	200	3.6	125	279	0.016	E
03	180	2.6	125	279	0.017	E
04	190	3.6	125	279	0.019	D
05	210	4.6	125	279	0.020	D
06	190	3.6	125	279	0.021	D
07	200	4.6	125	278	0.022	D
08	190	4.1	125	278	0.018	D
09	190	4.1	125	278	0.014	C
10	170	4.1	125	282	0.011	C
11	200	5.1	300	286	0.007	D
12	220	7.7	320	287	0.003	D
13	220	6.7	380	288	0.003	D
14	220	6.2	420	289	0.003	D
15	200	6.7	180	289	0.007	D
16	190	7.2	125	289	0.010	D
17	170	4.1	125	287	0.014	E
18	150	2.6	125	284	0.017	E
19	150	3.6	125	283	0.021	E
20	160	3.6	125	282	0.020	E
21	160	3.1	125	282	0.019	E
22	150	3.6	125	281	0.018	D
23	150	4.1	125	280	0.017	D
24	160	4.1	125	278	0.016	D

The wind speed from the four rawinsonde flights at the Greater Pittsburgh Airport were averaged and a logarithmic least-squares regression curve was fitted to the data following the procedure described in Section 3.3. From the regression curve, a wind-profile exponent of 0.25 was determined to be representative of conditions within the surface mixing layer, and this value of p was used in the calculations for all hours of 18 January 1973.

6.3 THE 13 JULY 1973 AIR POLLUTION EPISODE AT LIBERTY BOROUGH

6.3.1 Background

As mentioned above, two of the three 24-hour air pollution episodes selected for testing the performance of the short-term concentration model were evidenced by high SO_2 concentrations observed at the Liberty Borough monitor. This monitor is located approximately 2.4 kilometers north-northeast of the Clairton Coke Works. During 1973, observation at the Liberty Borough monitor showed that the 24-hour Primary Air Quality Standard for SO_2 of 365 micrograms per cubic meter was exceeded 16 times. One of these, the 18 January 1973 episode, has been used to test the performance of the short-term concentration model as described in Section 6.2. The second 24-hour period of observed high SO_2 concentrations at the Liberty Borough monitor selected for testing the short-term model occurred on 13 July 1973. Meteorological conditions on this date differed from those on 18 January 1973 principally in that the winds were generally from the west-southwest rather than from the south-southwest and the daytime mixing depths on 13 July 1973 were much larger than on 18 January 1973. Although the observations at the Liberty Borough monitor on 13 July 1973 are somewhat below the 24-hour Primary Air Quality Standard, this date was selected because it represents a summer situation in which very high SO_2 concentrations were observed.

The calculation procedures and the results of the 13 July 1973 short-term concentration calculations are presented in Section 6.3.2. Emissions data and meteorological data used in the calculations are given in Sections 6.3.3 and 6.3.4

6.3.2 Calculation Procedures and Results

The emissions and meteorological data in Sections 6.3.3 and 6.3.4 were used with the short-term concentration model described in Section A.3 of Appendix A to calculate hourly ground-level SO_2 concentrations for 649 grid points on a 21-kilometer by 28-kilometer grid that includes most of the area shown in Figure 6-8. The procedures described in Section A.5 of Appendix A were used to take into account the effects of variations in terrain height over the calculation grid. It should be noted that no calibration constants were used to scale the calculated concentrations to the concentrations observed at monitoring sites. The model concentrations were thus obtained directly from the reported emissions data and meteorological data with no calibration adjustment.

Figure 6-8 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentration for 13 July 1973. Neglecting the ambient SO_2 background concentration, the results indicate that the 24-hour Primary Air Quality Standard was exceeded in an area of elevated terrain on the east side of the Monongahela River, approximately 1.5 kilometers northeast of the Clairton Coke Works; and, in an area along the Monongahela River just west of Elizabeth and approximately 3 kilometers northeast of the Elrama power plant. At the grid point northeast of the Clairton Coke Works where the maximum calculated 24-hour average concentration of 842 micrograms per cubic meter occurs, the coke ovens of the Clairton Coke Works account for 23 percent of the calculated maximum and the Clairton Claus plant accounts for 64 percent. Similarly, the contributions from the Elrama and Mitchell power plants are respectively 9 and 3 percent of the total calculated maximum. The maximum 24-hour concentration calculated in the area west of Elizabeth is 450 micrograms per cubic meter. Emissions from Elrama and Mitchell account for 95 and 5 percent, respectively, of the total concentration.

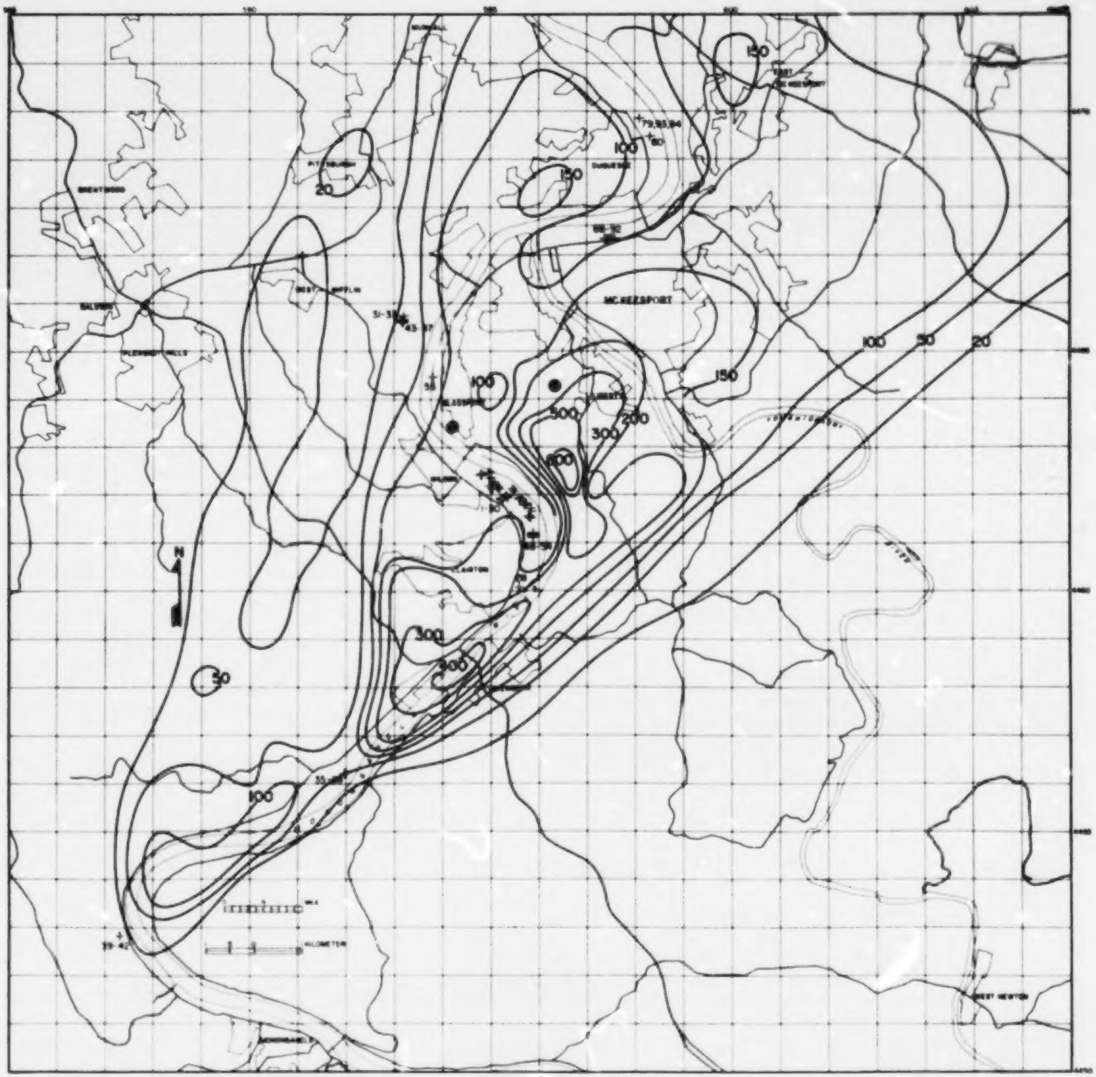
150
100
20
150
MCKEESPORT
100
50
20
150
100
500
200
300
600
CLAIRTON
N
300
300
50
100

FIGURE 6-8. Isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter calculated for the Clairton-Liberty Borough area on 13 July 1973. The two filled circles show the locations of the Glassport and Liberty Borough SO_2 monitors.

Table 6-8 gives the calculated and observed hourly average SO_2 concentration for 13 July 1973 at the Glassport and Liberty Borough SO_2 monitors. The locations of the monitors are shown by the filled circles in Figure 6-8. The calculated and observed 24-hour average concentrations given at the bottom of Table 6-8 are in reasonably good agreement, especially in view of the large gradient shown in the calculated concentration isopleths immediately south of the Liberty Borough monitor and the fact that the calculated isopleths do not include any background. The maximum 3-hour concentration calculated for the Glassport monitor of 496 micrograms per cubic meter is about 26 percent higher than the observed 3-hour maximum of 395 micrograms per cubic meter. The maximum 3-hour concentration calculated for the Liberty Borough monitor of 1204 micrograms per cubic meter is about 47 percent higher than the observed 3-hour maximum of 820 micrograms per cubic meter. There is, however, poor agreement between the hour-by-hour calculated and observed concentrations at the two monitors. As explained in Section 6.2, this is principally due to a fundamental lack of accuracy in the available wind-direction data which precludes the accurate positioning of plumes with respect to specific grid points on an hourly basis. For periods of 24 hours, however, the effects of inaccuracies in the hourly meteorological data are considerably reduced by the averaging process. The small calculated hourly concentrations after 0800 EST at the two monitors are explained by a shift in the reported wind directions of about 20 degrees toward the southwest and west-southwest.

Table 6-9 lists, for the major sources and source complexes independently and for the combined sources, the 24-hour average ground-level SO_2 concentrations calculated for the Glassport and Liberty Borough monitors. The results indicate that, on 13 July 1973, the SO_2 emissions from the Elrama power plant controlled the SO_2 levels at the Glassport monitor, while emissions from both the Clairton Coke Works and the Elrama power plant controlled the SO_2 levels at the Liberty Borough monitor.

TABLE 6-8

CALCULATED AND OBSERVED HOURLY GROUND-LEVEL SO_2 CONCENTRATIONS AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITOR ON 13 JULY 1973

Hour (EST)	Glassport Monitor		Liberty Borough Monitor	
	Calculated Concentration ($\mu g/m^3$)	Observed Concentration ($\mu g/m^3$)	Calculated Concentration ($\mu g/m^3$)	Observed Concentration ($\mu g/m^3$)
01	779*	73	643	1245
02	618*	224	523*	354
03	92*	133	1615*	398
04	85	252	1473*	374
05	708	582*	431	486
06	109	179*	836	1017*
07	1	424*	93	502*
08	25	255	267	941*
09	1	107	72	512
10	0	120	6	416
11	0	68	4	195
12	0	70	0	213
13	0	73	22	257
14	0	83	71	198
15	0	94	72	161
16	0	107	0	263
17	0	86	0	260
18	0	83	0	208
19	0	99	6	283
20	0	94	6	140
21	0	91	27	138
22	0	18	0	44
23	0	8	28	18
24	0	10	0	31
24-Hour Average	101	139	258	361
*3-Hour Maximum	496	395	1204	820

TABLE 6-9

CALCULATED 24-HOUR AVERAGE GROUND-LEVEL SO_2 CONCENTRATIONS AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITORS ON 13 JULY 1973

Source	24-Hour Average Concentration ($\mu g/m^3$)			
	Glassport Monitor		Liberty Borough Monitor	
Clairton				
Coke Ovens	0 (0%)		70 (27%)	
Power Boilers	0 (0%)		47 (18%)	
Reheat and Blast Furnaces	0 (0%)		5 (2%)	
Claus Plant	0 (0%)		23 (9%)	
All Sources		0 (0%)		144 (56%)
Irvin				
Process	0 (0%)		0 (0%)	
Reheat	0 (0%)		0 (0%)	
All Sources		0 (0%)		0 (0%)
Elrama		89 (88%)		105 (41%)
Mitchell		12 (12%)		9 (3%)
Pitron		0 (0%)		0 (0%)
Combined Sources		101 (100%)		258 (100%)

*Numbers inclosed in parentheses show the percentage of the total calculated concentration allocated to each source.

6.3.3 Source Data

Table 6-10 lists the sources, source locations, SO_2 emission rates and stack parameters used to calculate short-term ground-level SO_2 concentrations for the 13 July 1973 air pollution episode at Liberty Borough. The source and emissions data in Table 6-10 were provided by the Allegheny County Bureau of Air Pollution Control. The locations of the sources are shown in Figure 6-8 and on a topographic map of the Clairton-Liberty Borough area in Figure 4-1 of Section 4.

6.3.4 Meteorological Data

Table 6-11 lists by hour the wind directions, surface wind speeds, ambient air temperatures and vertical potential temperature gradients used in the calculations for the 13 July 1973 air pollution episode at Liberty Borough. The hourly wind speeds and directions are averages of concurrent pairs of observations at the Greater Pittsburgh Airport and Allegheny County Airport. The ambient air temperatures, which are the temperatures measured at the Greater Pittsburgh Airport, were used with rawinsonde data obtained from the Greater Pittsburgh Airport at 1900 EST on 12 July, at 0700 EST and 1900 EST on 13 July, and at 0700 EST on 14 July to estimate the mixing depths listed in Table 6-11. Measurements of the vertical potential temperature gradient were obtained from the four Greater Pittsburgh Airport rawinsonde flights. An adiabatic thermal stratification was assumed to exist at the time of the maximum temperature (1500 EST). Vertical potential temperature gradients for intermediate hours were obtained by linear interpolation. The wind speeds from the rawinsonde data were averaged and a least-squares regression curve was fitted to the data to obtain a wind-profile exponent p of 0.14. Details of the least-squares procedure are given in Section 3.3. Applying the Turner (1964) definitions of the Pasquill stability categories, the Pasquill stability category D

TABLE 6-10

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE SHORT-TERM SO_2 CONCENTRATIONS FOR THE 13 JULY 1973 AIR POLLUTION EPISODE AT LIBERTY BOROUGH

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
1 Clairton Underfire #1	595,860	4,461,520	1.58	69	700	37.27	1.220
2 Clairton Underfire #2	595,830	4,461,540	1.58	69	700	37.27	1.220
3 Clairton Underfire #3	595,730	4,461,780	1.58	69	700	37.27	1.220
7 Clairton Underfire #7	595,880	4,461,650	1.58	65	700	35.87	1.270
8 Clairton Underfire #8	595,870	4,461,680	1.58	65	700	35.87	1.270
9 Clairton Underfire #9	595,750	4,461,810	1.58	65	700	35.87	1.270
10 Clairton Underfire #10	595,660	4,461,900	1.58	69	700	37.27	1.220
11 Clairton Underfire #11	595,630	4,461,920	1.58	69	700	37.27	1.220
12 Clairton Underfire #12	595,520	4,462,060	1.58	69	700	37.27	1.220
13 Clairton Underfire #13	595,380	4,461,930	1.58	69	700	37.74	1.310
14 Clairton Underfire #14	595,360	4,461,960	1.58	69	700	37.74	1.310
15 Clairton Underfire #15	595,210	4,462,110	1.58	69	700	37.74	1.310
16 Clairton Underfire #16	595,190	4,462,150	1.58	61	700	32.13	1.310
17 Clairton Underfire #17	595,110	4,462,240	1.58	61	700	32.13	1.310

TABLE 6-10 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
18 Clairton Underfire #18	595,020	4,462,330	1.58	76	700	32.300	1.460
19 Clairton Underfire #19	595,280	4,461,880	1.58	76	700	58.430	2.140
20 Clairton Underfire #20	595,250	4,461,910	1.58	76	700	58.430	2.140
21 Clairton Underfire #21	595,060	4,462,120	1.58	76	700	58.430	2.140
22 Clairton Underfire #22	595,030	4,462,160	1.58	76	700	58.430	2.140
23 Clairton Underfire #12A	595,500	4,462,080	1.58	69	700	35.870	1.520
24 Clairton B&W #1	595,000	4,462,470	10.22	50	455	92.570	1.370
25 Clairton CE #2	595,000	4,462,470	3.22	50	455	72.330	1.060
26 Clairton Benzene Boiler	594,870	4,462,400	1.61	52	16*	60.000*	--
27 Clairton Benzene Boiler	594,850	4,462,410	1.61	52	16*	60.000*	--
28 Clairton Blast Furnace	595,630	4,460,060	0.83	60	716	180.580	1.880
30 Clairton Claus Plant	595,810	4,461,550	13.90	46	561	18.030	.610
31 Irvin 3 and 4	593,220	4,465,600	2.26	55	646	54.550	1.790
32 Irvin 5 and 6	593,230	4,465,650	3.38	78	633	79.620	1.600
33 Irvin 7	593,250	4,465,710	2.57	30	483	33.400	.920
35 Elrama	592,000	4,456,200	39.73	83	416	198.950	2.150

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 6-10 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
36 Elrama	592,000	4,456,200	42.52	83	430	198.950	2.150
37 Elrama	592,000	4,456,200	45.79	83	430	229.450	2.150
38 Elrama	592,000	4,456,200	68.86	89	416	299.140	2.300
39 Mitchell	587,340	4,452,810	0	73	403	534.810	3.050
40 Mitchell	587,340	4,452,810	15.83	70	467	223.640	2.150
41 Mitchell	587,340	4,452,810	15.83	70	467	223.640	2.150
42 Mitchell	587,340	4,452,810	15.83	70	467	223.640	2.150
43 Irvin Reheat	593,250	4,465,600	1.0	52	10*	50.000*	--
44 Irvin Reheat	593,250	4,465,700	1.0	52	10*	50.000*	--
45 Irvin Reheat	593,250	4,465,650	1.0	52	10*	50.000*	--
46 Irvin Reheat	593,260	4,465,600	1.0	52	10*	50.000*	--
47 Irvin Reheat	593,260	4,465,650	1.0	52	10*	50.000*	--
48 Clairton Reheat	595,100	4,461,520	0.36	52	70*	70.000*	--
49 Clairton Reheat	595,100	4,461,530	0.36	52	70*	70.000*	--
50 Clairton Reheat	595,100	4,461,540	0.36	52	70*	70.000*	--
51 Clairton Reheat	595,100	4,461,500	0.36	52	70*	70.000*	--

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 6-10 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
52 Clairton Reheat	595, 100	4, 461, 560	0. 36	52	70*	70. 000*	--
53 Clairton Reheat	595, 100	4, 461, 570	0. 36	52	70*	70. 000*	--
54 Clairton Reheat	595, 100	4, 461, 580	0. 36	52	70*	70. 000*	--
55 Pittron	593, 850	4, 464, 500	0. 11	75	600	88. 000	2. 000

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 6-11

METEOROLOGICAL INPUT PARAMETERS FOR 13 JULY 1973

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	195	3.6	125	290	0.007	D
02	195	4.6	125	291	0.007	D
03	210	4.6	125	291	0.008	D
04	210	5.1	125	291	0.008	D
05	200	5.7	125	291	0.009	D
06	215	6.2	125	292	0.009	D
07	225	6.4	200	293	0.010	D
08	220	5.7	350	295	0.009	C
09	225	6.9	500	297	0.008	D
10	230	6.4	750	299	0.006	D
11	235	6.4	900	301	0.005	C
12	260	6.2	1000	303	0.004	C
13	230	6.9	1050	303	0.003	C
14	225	6.4	1200	304	0.001	D
15	225	6.2	1700	305	0.000	D
16	240	7.5	1200	304	0.001	D
17	235	7.2	1220	304	0.001	D
18	240	7.2	1050	304	0.002	D
19	230	6.4	1000	303	0.002	D
20	230	5.7	825	300	0.003	D
21	225	4.4	650	298	0.004	E
22	230	4.6	475	297	0.004	E
23	225	4.6	300	297	0.005	E
24	230	4.6	125	295	0.006	E

was assigned to 16 hours while the C and E categories were each assigned to 4 hours. The urban-area hourly lateral and vertical turbulent intensities given in Table 3-5 for the various Pasquill stability categories were also used in the 13 July 1973 short-term model calculations.

SECTION 7

SHORT-TERM COMPLIANCE CALCULATIONS

A major objective of this study is to calculate by means of an appropriate diffusion model the maximum 3-hour and 24-hour ground-level SO_2 concentrations that may be expected to occur in Allegheny County under the current SO_2 emission regulations for large stationary sources. The purpose of these calculations is to assist the U. S. Environmental Protection Agency in determining the extent to which these proposed emission regulations will ensure the attainment and maintenance of the Federal short-term Air Quality Standards for SO_2 in Allegheny County. Bloom and Smith (1974) have noted that all violations of the 3-hour Secondary Air Quality Standard recorded in Allegheny County since 1971 occurred during 24-hour periods when the 24-hour Primary Air Quality Standard was also violated, and we concur that the 24-hour is the more restrictive. We therefore have emphasized the 24-hour standard in the short-term compliance calculations.

As previously noted in Section 5.1, the Allegheny County Bureau of Air Pollution Control supplied SO_2 emissions data for Compliance Cases A, B and C covering the major SO_2 sources and source complexes included in the 1973 model calculations described in Sections 4 and 6. The emissions data for Compliance Case A were used in combination with assumed worst-case meteorological conditions to calculate short-term ground-level SO_2 concentrations for three specific areas within Allegheny County: Logans Ferry, Clairton-Liberty Borough, and Hazelwood-Braddock. The calculation procedures and results of the calculations, as well as the source parameters and meteorological parameters used in the short-term model calculations for each of three areas, are described below. As explained in Section 5.1, differences in SO_2 emissions for the three Compliance Cases are slight and have a negligible effect on the calculated ground-level SO_2 concentrations. Therefore, only the results for Compliance Case A emissions are presented.

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7.1 SHORT-TERM COMPLIANCE CALCULATIONS FOR THE LOGANS FERRY AREA

7.1.1 Background

As explained in Section 6.1, the short-term model calculations for the 4 January 1973 air pollution episode at Logans Ferry showed that emissions from the West Penn power plant were primarily responsible for the excessively high SO_2 concentrations observed at the Logans Ferry monitor. The meteorological conditions associated with the 4 January 1973 episode (moderate to strong west-southwest winds and Pasquill stability category D) were selected to be representative of worst-case meteorological conditions for the Logans Ferry short-term compliance calculations.

The calculation procedures and results are presented in Section 7.1.2. The computed emissions data are given in Section 7.1.3 and the meteorological data used in the Logans Ferry short-term compliance calculations are described in Section 7.1.4.

7.1.2 Calculation Procedures and Results

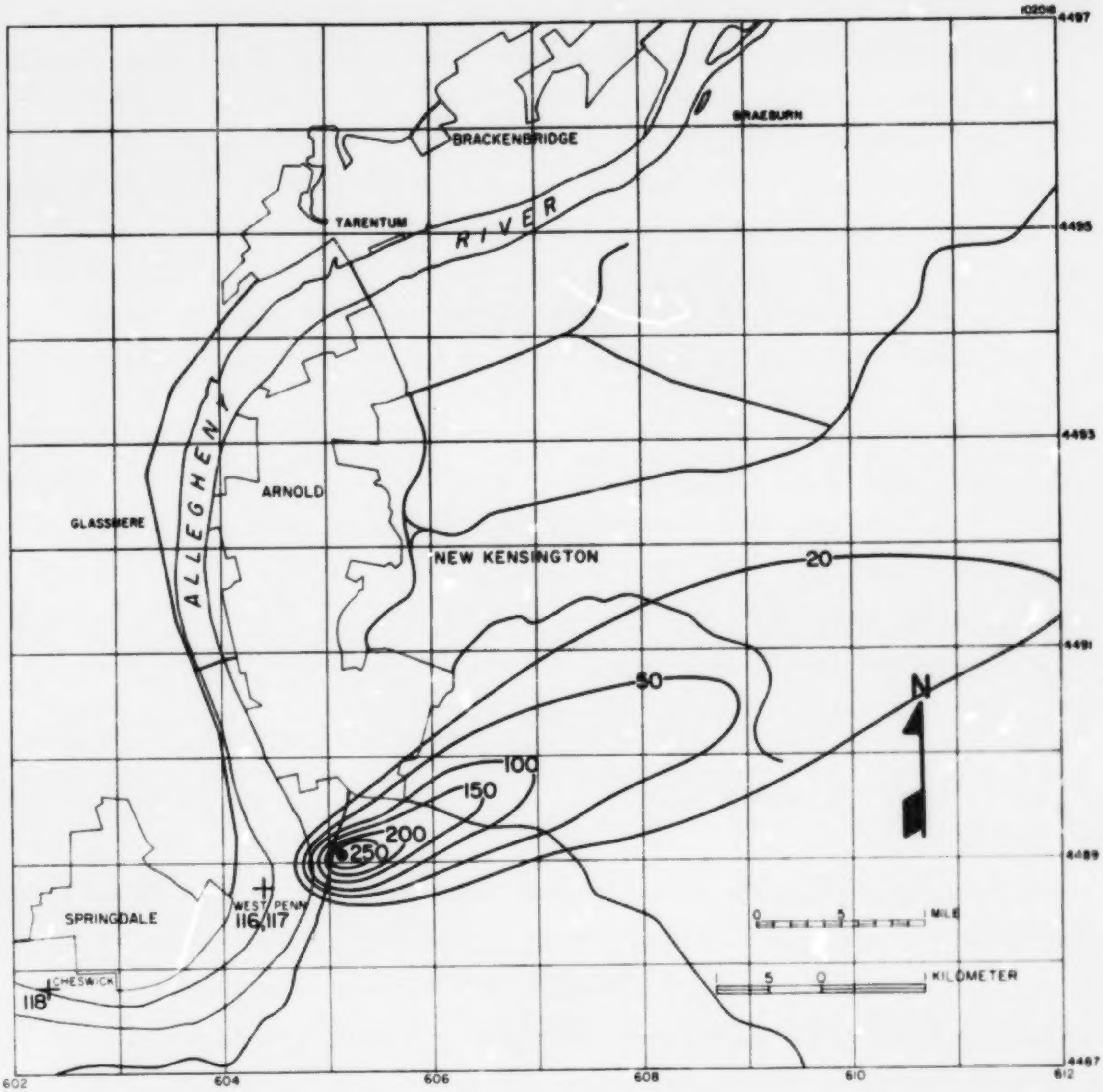
The source and meteorological data in Sections 7.1.3 and 7.1.4 were used with the short-term concentration model described in Section A.3 of Appendix A to calculate hourly ground-level SO_2 concentrations for 256 grid points on the 10-kilometer by 10-kilometer grid in Figure 6-1 of Section 6. The procedures described in Section A.5 of Appendix A were used to account for the effects of variations in terrain height over the calculated grid.

Figure 7-1 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentration. Neglecting the ambient SO_2 background, Figure 7-1 does not show that the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter is exceeded. However, the maximum calculated 24-hour concentration of 458 micrograms per cubic meter, which occurs at the grid point corresponding to the location of the Logans Ferry SO_2 monitor, is above the 24-hour standard. The location of the monitor is given by the filled circle in Figure 7-1. The second highest calculated 24-hour concentration is 265 micrograms per cubic meter and this occurs at a grid point located 0.2 kilometers from the Logans Ferry monitor. Thus, the 24-hour standard may be exceeded in a very small area under worst-case meteorological conditions.

Table 7-1 gives the calculated hourly SO_2 concentrations at the Logans Ferry monitor due to the SO_2 emissions from each power plant independently and from both power plants combined. According to Table 7-1, the West Penn emissions account for about 97 percent of the calculated maximum short-term concentrations. A similar result was obtained in the short-term calculations for the 4 January 1973 air pollution episode at Logans Ferry described in Section 6.1. The calculated maximum 1-hour and 3-hour concentrations are 981 and 748 micrograms per cubic meter, respectively. Thus, the Logans Ferry compliance calculations indicate that the projected SO_2 emissions will not endanger the 3-hour Secondary Air Quality Standard of 1300 micrograms per cubic meter.

7.1.3 Source Data

Table 7-2 lists the sources, source locations SO_2 emission rates and stack parameters used to calculate short-term ground-level SO_2 concentrations for the Logans Ferry short-term compliance case. The locations of the West Penn and Cheswick power plants are shown in Figure 7-1. Comparison of Table 7-2 with Table 6-2 in Section 6 shows that, for the compliance case, the total SO_2 emissions from the West Penn power plant are reduced to about 34 percent of the 4 January 1973 levels and that the Cheswick emissions are reduced to about 32 per-


4497
BRAEBURN
BRACKENBRIDGE
TARENTUM
RIVER
4495
4493
ALLEGHENY
ARNOLD
GLASSMERE
NEW KENSINGTON
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4491
50
N
100
150
200
250
4489
WEST PENN
116,117
SPRINGDALE
MILE
KILOMETER
CHESWICK
118
4487
602
604
606
608
610
612

FIGURE 7-1. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter for the Logans Ferry compliance case. The location os the Logans Ferry SO_2 monitor is shown by the filled circle.

TABLE 7-1

CALCULATED HOURLY GROUND-LEVEL SO_2 CONCENTRATIONS AT THE LOGANS FERRY MONITOR FOR THE COMPLIANCE CASE

Hour (EST)	Hourly SO_2 Concentration ($\mu g/m^3$)		
	West Penn	Cheswick	Combined Sources
01	47	1	48
02	373	11	384
03	86	2	87
04	465	15	480
05	947	34	981
06	154	4	158
07	151	4	155
08	617	25	642
09	629	24	652
10	642	23	666
11	655	22	677
12	605	20	625
13	629	24	652
14	650	21	671
15	120	3	123
16	502	25	527
17	940	32	972
18	716	28	744
19	492	13	505
20	494	19	513
21	345	17	362
22	260	10	270
23	7	0	7
24	83	3	86
24-Hour Average	442	16	458

TABLE 7-2

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE SHORT-TERM GROUND-LEVEL SO_2 CONCENTRATIONS FOR THE COMPLIANCE CASE AT LOGANS FERRY

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
116 West Penn	604,380	4,488,740	8.08	67.1	472	160.98	2.60
117 West Penn	604,380	4,488,740	12.39	62.5	444	162.14	1.85
118 Cheswick	602,330	4,487,800	38.02	229.0	411	881.46	3.20

cent of their 4 January 1973 levels. It should be noted that the Logans Ferry short-term compliance calculations do not include the effects of ambient background or of any SO_2 sources other than the West Penn and Cheswick power plants.

7.1.4 Meteorological Data

Table 7-3 lists, for each hour, the wind direction, surface wind speed, mixing depth, ambient air temperature and vertical potential temperature gradient used in the calculations for the Logans Ferry short-term compliance case. The parameters given in Table 7-3 are representative of neutral stability in combination with moderate to strong winds from the west-southwest. This meteorological condition is similar to the situation that produced the air pollution episode at Logans Ferry on 4 January 1973, except that west-southwest winds with speeds above 5.1 meters per second are assumed to persist throughout the entire 24-hour period. Table 3-10 of Section 3 indicates that west-southwest winds greater than 5.1 meters per second persisted at the Greater Pittsburgh Airport for 24 or more hours, a total of 7 times during the period 1963 through 1972. Thus, the assumption of a 24-hour persistence of west-southwest winds with speeds greater than 5.1 meters per second appears to be reasonable. The wind-profile exponent was set equal to the value of 0.17 calculated for the 4 January 1973 episode (see Section 6.1.4) and the hourly lateral and vertical turbulent intensities were set equal to the urban values for Pasquill stability category D of 0.1051 and 0.0735 radians, respectively shown in Table 3-5.

7.2 SHORT-TERM COMPLIANCE CALCULATIONS FOR THE CLAIRTON-LIBERTY BOROUGH AREA

7.2.1 Background

Air quality observations at the Glassport and Liberty Borough monitors operated by the Allegheny County Bureau of Air Pollution Control have shown that

TABLE 7-3

METEOROLOGICAL INPUT PARAMETERS FOR THE LOGANS FERRY SHORT-TERM COMPLIANCE CASE CALCULATIONS

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	235	6.2	1000	280	0	D
02	240	6.7	1000	280	0	D
03	235	10.3	1000	280	0	D
04	240	9.8	1000	280	0	D
05	245	8.2	1000	280	0	D
06	255	9.3	1000	280	0	D
07	255	9.8	1000	280	0	D
08	250	10.3	1000	280	0	D
09	250	9.3	1000	280	0	D
10	250	8.7	1000	280	0	D
11	250	8.2	1000	280	0	D
12	250	7.2	1000	280	0	D
13	250	9.3	1000	280	0	D
14	250	7.7	1000	280	0	D
15	255	6.7	1000	280	0	D
16	245	6.2	1000	280	0	D
17	245	7.7	1000	280	0	D
18	245	6.7	1000	280	0	D
19	240	7.7	1000	280	0	D
20	250	6.7	1000	280	0	D
21	250	6.2	1000	280	0	D
22	240	6.2	1000	280	0	D
23	260	6.2	1000	280	0	D
24	255	6.2	1000	280	0	D

the highest ground-level SO_2 concentrations occur with moderate to strong south-southwest winds (episodes of this type which occurred on 18 January 1973 and 13 July 1973 are discussed in Sections 6.2 and 6.3). For the Clairton-Liberty Borough short-term compliance calculations, a meteorological regime similar to that of 18 January 1973, which included low mixing depths as well as moderate south-southwest winds, was assumed to represent worst-case meteorological conditions.

The calculation procedures and the results of the calculations are given in Section 7.2.2. The projected emissions data for Compliance Case A and the meteorological data used in the calculations are presented in Sections 7.2.3 and 7.2.4.

7.2.2 Calculation Procedures and Results

The source and meteorological data in Sections 7.2.3 and 7.2.4 were used with the short-term concentration model described in Section A.3 of Appendix A to calculate the hourly ground-level SO_2 concentrations for 649 grid points on a 21-kilometer by 28-kilometer grid that includes most of the area shown in Figure 7-2. The effects of variations in terrain height over the calculation grid were included in the calculations following the procedures outlined in Section A.5 of Appendix A.

Figure 7-2 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentration. Neglecting the ambient SO_2 background, the compliance calculations indicate that the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter will not be exceeded. The maximum calculated concentration of 310 micrograms per cubic meter is at the grid point located at the site of the Liberty Borough SO_2 monitor. Table 7-5 lists, for the major sources complexes independently and for the combined sources, the 24-hour average ground-level SO_2 concentrations calculated for the Glassport and Liberty Borough monitors. The locations of the monitors are shown by the two filled circles in Figure 7-2.

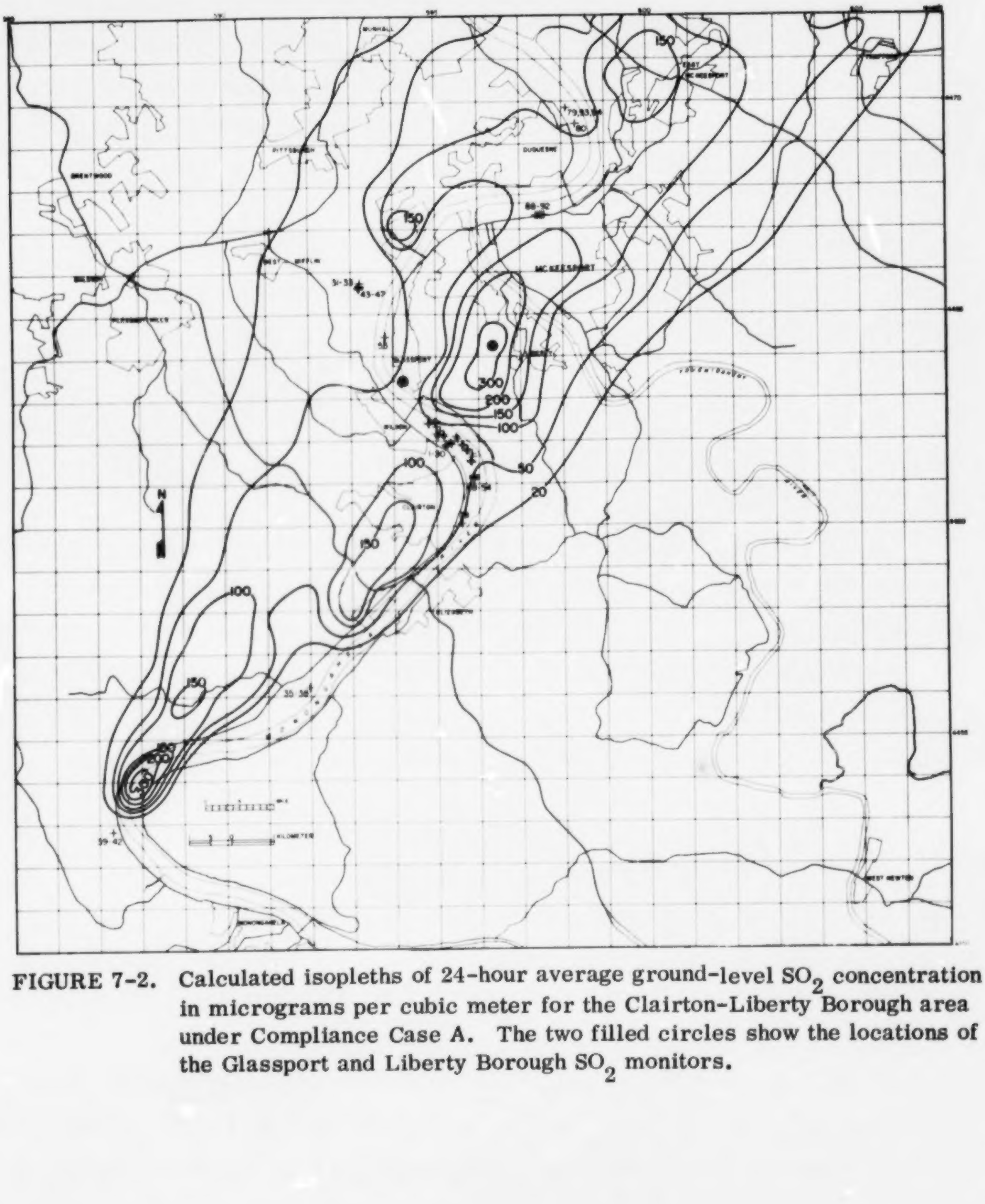
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FIGURE 7-2. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter for the Clairton-Liberty Borough area under Compliance Case A. The two filled circles show the locations of the Glassport and Liberty Borough SO_2 monitors.

TABLE 7-4

CALCULATED 24-HOUR AVERAGE GROUND-LEVEL SO_2 CONCENTRATIONS AT THE GLASSPORT AND LIBERTY BOROUGH SO_2 MONITORS FOR COMPLIANCE CASE A

Source	24-Hour Average Concentration ($\mu g/m^3$)			
	Glassport Monitor		Liberty Borough Monitor	
Clairton				
Coke Ovens	0 (0%)		53 (17%)	
Power Boilers	0 (0%)		145 (47%)	
Reheat and Blast Furnaces	0 (0%)		9 (3%)	
Claus Plant	0 (0%)		5 (2%)	
All Sources		0 (0%)		212 (68%)
Irvin				
Process	0 (0%)		0 (0%)	
Reheat	0 (0%)		0 (0%)	
All Sources		0 (0%)		0 (0%)
Elrama		32 (56%)		70 (23%)
Mitchell		25 (44%)		28 (9%)
Pittron		0 (0%)		0 (0%)
Combined Sources		57 (100%)		310 (100%)

*Numbers inclosed in parentheses show the percentage of the total calculated concentration allocated to each source.

As shown by Table 7-4, the relative contributions to the total calculated 24-hour concentration at the Liberty Borough monitor from the Clairton Coke Works, Elrama power plant and Mitchell power plant are 68, 23 and 9 percent, respectively. Similarly, at the Glassport monitor, 56 percent of the total calculated 24-hour concentration is contributed by the Elrama power plant and 44 percent is contributed by the Mitchell power plant. Because of the mean wind directions used in the calculations, SO_2 emissions from the Clairton Coke Works do not contribute to the concentration calculated at the Glassport monitor.

The calculated maximum hourly ground-level SO_2 concentration is 952 micrograms per cubic meter and the calculated maximum 3-hour concentration is 699 micrograms per cubic meter. Emissions from the Clairton Coke Works account for all of the maximum hourly concentration, which is located on the elevated terrain northeast of the plant. The 3-hour maximum is located 1.3 kilometers north-northeast of the Mitchell power plant, and emissions from the Mitchell plant are responsible for all of this calculated concentration. Because the maximum calculated hourly and 3-hour concentrations are well below the 3-hour Secondary Air Quality Standard of 1300 micrograms per cubic meter, it appears that the reductions in SO_2 emissions for Compliance Case A are sufficient to maintain the 3-hour standard in the Clairton-Liberty Borough area.

7.2.3 Source Data

Table 7-5 lists the sources, source locations, SO_2 emission rates and stack parameters used to calculate short-term ground-level SO_2 concentrations for the Clairton-Liberty Borough Compliance Case A. The locations of the sources are shown in Figure 7-2. A comparison of Table 7-5 with Table 4-2 of Section 4 reveals that total SO_2 emissions from the Clairton Coke Works, Elrama power plant and Mitchell power plant under Compliance Case A are reduced to about 39, 22 and 26 percent, respectively, of the emissions given in the 1973 emissions

TABLE 7-5

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE SHORT-TERM GROUND-LEVEL SO_2 CONCENTRATIONS FOR THE CLAIRTON-LIBERTY BOROUGH COMPLIANCE CASE A

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
1 Clairton Underfire #1	595,860	4,461,520	.33	69	700	37.27	1.220
2 Clairton Underfire #2	595,830	4,461,540	.33	69	700	37.27	1.220
3 Clairton Underfire #3	595,730	4,461,780	.33	69	700	37.27	1.220
7 Clairton Underfire #7	595,880	4,461,650	.33	65	700	35.87	1.270
8 Clairton Underfire #8	595,870	4,461,680	.33	65	700	35.87	1.270
9 Clairton Underfire #9	595,750	4,461,810	.33	65	700	35.87	1.270
10 Clairton Underfire #10	595,660	4,461,900	.33	69	700	37.27	1.220
11 Clairton Underfire #11	595,630	4,461,920	.33	69	700	37.27	1.220
12 Clairton Underfire #12	595,520	4,462,060	.33	69	700	37.27	1.220
13 Clairton Underfire #13	595,380	4,461,930	.33	69	700	37.74	1.310
14 Clairton Underfire #14	595,360	4,461,960	.33	69	700	37.74	1.310
15 Clairton Underfire #15	595,210	4,462,110	.33	69	700	37.74	1.310
16 Clairton Underfire #16	595,190	4,462,150	.33	61	700	32.13	1.310
17 Clairton Underfire #17	595,110	4,462,240	.33	61	700	32.13	1.310

TABLE 7-5 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
18 Clairton Underfire #18	595,020	4,462,330	.33	76	700	32.300	1.460
19 Clairton Underfire #19	595,280	4,461,880	.33	76	700	58.430	2.140
20 Clairton Underfire #20	595,250	4,461,910	.33	76	700	58.430	2.140
21 Clairton Underfire #21	595,060	4,462,120	.33	76	700	58.430	2.140
22 Clairton Underfire #22	595,030	4,462,160	.33	76	700	58.430	2.140
23 Clairton Underfire #12A	595,500	4,462,080	.33	69	700	35.870	1.520
24 Clairton B&W #1	595,000	4,462,470	5.65	50	455	92.570	1.370
25 Clairton CE #2	595,000	4,462,470	4.21	50	455	72.330	1.060
26 Clairton Benzene Boiler	594,870	4,462,400	1.98	52	16*	60.000*	--
27 Clairton Benzene Boiler	594,850	4,462,410	1.98	52	16*	60.000*	--
28 Clairton Blast Furnace	595,630	4,460,060	.82	60	716	180.580	1.880
30 Clairton Claus Plant	595,810	4,461,550	3.87	46	561	18.030	.610
31 Irvin 3 and 4	593,220	4,465,600	1.87	55	646	54.550	1.790
32 Irvin 5 and 6	593,230	4,465,650	2.66	78	633	79.620	1.600
33 Irvin 7	593,250	4,465,710	2.07	30	483	33.400	.920
35 Elrama	592,000	4,456,200	0	83	416	198.950	2.150

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 7-5 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
36 Elrama	592,000	4,456,200	0	83	430	198.950	2.150
37 Elrama	592,000	4,456,200	0	83	430	229.450	2.150
38 Elrama	592,000	4,456,200	35.6	89	416	299.140	2.300
39 Mitchell	587,340	4,452,810	18.33	73	403	534.810	3.050
40 Mitchell	587,340	4,452,810	5.33	70	467	223.640	2.150
41 Mitchell	587,340	4,452,810	5.33	70	467	223.640	2.150
42 Mitchell	587,340	4,452,810	5.33	70	467	223.640	2.150
43 Irvin Reheat	593,250	4,465,600	.41	52	10*	50.000*	--
44 Irvin Reheat	593,250	4,465,700	.41	52	10*	50.000*	--
45 Irvin Reheat	593,250	4,465,650	.41	52	10*	50.000*	--
46 Irvin Reheat	593,260	4,465,600	.41	52	10*	50.000*	--
47 Irvin Reheat	593,260	4,465,650	.41	52	10*	50.000*	--
48 Clairton Reheat	595,100	4,461,520	.13	52	70*	70.000*	--
49 Clairton Reheat	595,100	4,461,530	.13	52	70*	70.000*	--
50 Clairton Reheat	595,100	4,461,540	.13	52	70*	70.000*	--
51 Clairton Reheat	595,100	4,461,500	.13	52	70*	70.000*	--

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 7-5 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
52 Clairton Reheat	595,100	4,461,560	.13	52	70*	70.000*	--
53 Clairton Reheat	595,100	4,461,570	.13	52	70*	70.000*	--
54 Clairton Reheat	595,100	4,461,580	.13	52	70*	70.000*	--
55 Pittron	593,850	4,464,500	.11	75	600	88.000	2.000

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

inventory compiled by the Allegheny County Bureau of Air Pollution Control. It should be noted that the Clairton-Liberty Borough short-term compliance calculations do not consider the ambient SO_2 background or the contributions of SO_2 sources other than those listed in Table 7-5.

7.2.4 Meteorological Data

Table 7-6 lists the hourly wind directions, surface wind speeds, mixing depths, ambient air temperatures and vertical potential temperature gradients used in the concentration calculations for the Clairton-Liberty Borough short-term Compliance Case A. These parameters were selected to be representative of a winter pre-frontal situation with persistent south-southwest winds greater than 3.1 meters per second, low mixing depths (125 to 300 meters), and overcast or broken sky conditions. Table 3-9 of Section 3 indicates that south-southwest winds greater than 3.1 meters per second persisted at the Greater Pittsburgh Airport for 12 or more hours 41 times during the period 1963 through 1972. Comparison of Tables 3-9 and 3-10 shows that the wind speed varied between 3.1 and 5.1 meters per second on 27 of the 41 occasions. Thus, a 12-hour persistence of south-southwest winds in the 3.1- to 5.1-meter per second range was assumed for the first 12 hours of the compliance case. Table 3-9 shows that south-southwest winds greater than 3.1 meters per second persisted for 24 or more hours once, and that southwest winds greater than 3.1 meters per second persisted for 24 or more hours 6 times, during the 10-year period. Therefore, the wind direction was constrained within a 30-degree sector for the entire 24-hour period. The mixing depths and vertical potential temperature gradients listed in Table 7-6 are similar to those observed during the air pollution episode at Liberty Borough on 18 January 1973 (see Section 6.2). The wind-profile exponent was set equal to the value of 0.25 used in the calculations for 18 January 1973. Because we assumed that broken to overcast skies persist throughout the 24-hour period, the lateral and vertical turbulent intensities were set equal to the urban values for Pasquill stability category D of 0.1051 and 0.0735 radians, respectively (see Table 3-5).

TABLE 7-6

METEOROLOGICAL INPUT PARAMETERS FOR THE CLAIRTON-LIBERTY BOROUGH SHORT-TERM COMPLIANCE CALCULATIONS

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	210	3.6	125	273	0.021	D
02	205	3.6	125	273	0.021	D
03	200	4.1	125	273	0.021	D
04	195	3.6	125	273	0.021	D
05	200	4.6	125	273	0.021	D
06	205	3.6	125	273	0.021	D
07	210	4.1	125	273	0.021	D
08	210	4.1	125	273	0.018	D
09	210	4.6	125	273	0.014	D
10	200	4.6	125	273	0.011	D
11	205	5.1	150	273	0.007	D
12	210	5.1	200	273	0.003	D
13	220	7.2	250	273	0.003	D
14	215	6.2	300	273	0.003	D
15	225	6.2	180	273	0.007	D
16	220	5.7	125	273	0.010	D
17	220	5.1	125	273	0.014	D
18	220	4.1	125	273	0.017	D
19	210	3.6	125	273	0.021	D
20	225	4.6	125	273	0.021	D
21	200	3.6	125	273	0.021	D
22	210	4.1	125	273	0.021	D
23	215	3.6	125	273	0.021	D
24	220	3.6	125	273	0.021	D

7.3 SHORT-TERM COMPLIANCE CALCULATIONS FOR THE HAZELWOOD-BRADDOCK AREA

7.3.1 Background

The meteorological conditions assumed in the Clairton-Liberty Borough short-term calculations for Compliance Case A (shallow mixing depths and moderate south-southwest winds) do not necessarily represent the worst-case meteorological conditions for the Hazelwood-Braddock area. Inspection of the source locations shown in Figure 7-3 indicates that west-northwest winds will maximize the superposition of plumes from the various sources in the Hazelwood-Braddock area. Moderate west-northwest winds in combination with shallow mixing depths were therefore assumed to represent worst-case meteorological conditions for the Hazelwood-Braddock short-term compliance calculations.

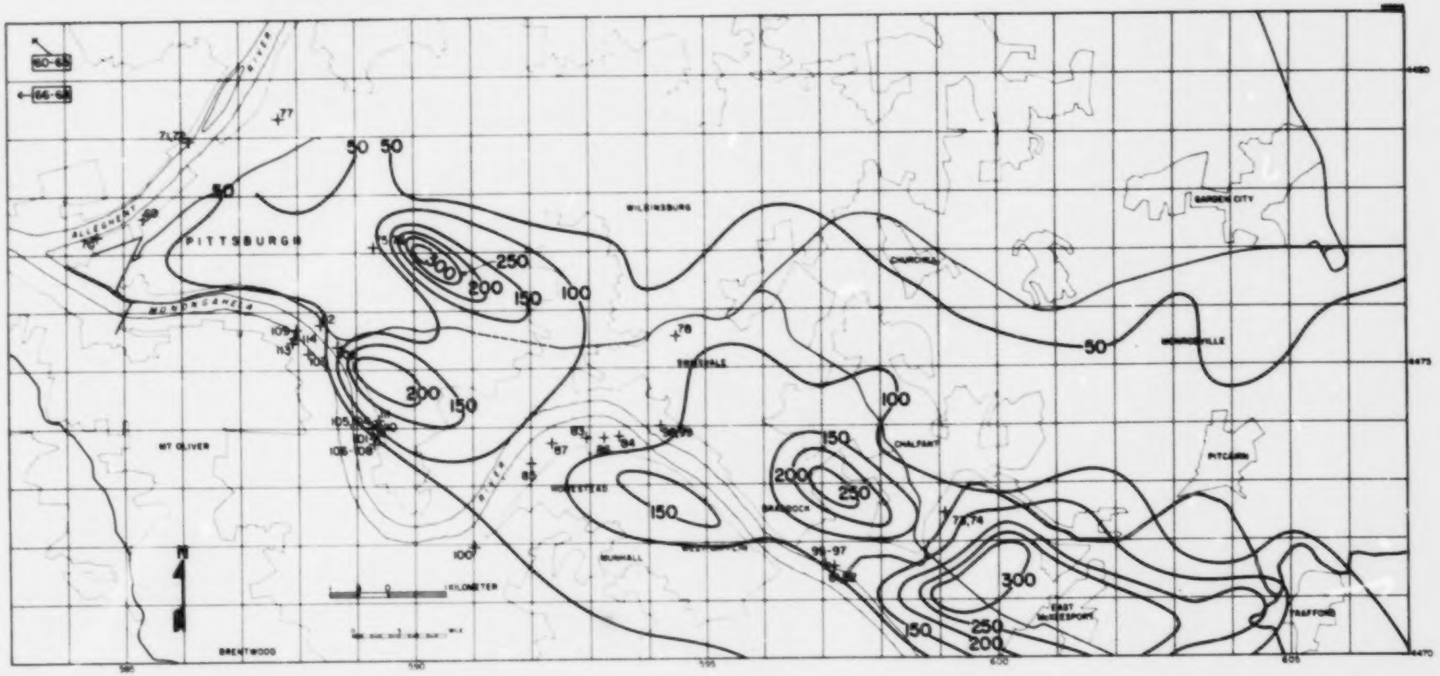
The calculation procedures and the results of the calculations are presented in Section 7.3.2. The emissions data for Compliance Case A and the meteorological data used in the Hazelwood-Braddock short-term compliance calculations are described in Sections 7.3.3 and 7.3.4.

7.3.2 Calculation Procedures and Results

The source and meteorological data in Sections 7.3.3 and 7.3.4 were used with the short-term concentration model described in Section A.3 of Appendix A to calculate hourly ground-level concentrations for 649 grid points on a 21-kilometer by 28-kilometer grid enclosed by the areas shown in Figures 7-3 and 7-4. The procedures described in Section A.5 of Appendix A were used to account for the effects of variations in terrain height over the calculation grid.

Figure 7-3 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentration for the Hazelwood-Braddock area. Neglecting the ambient SO_2 background, Figure 7-3 does not indicate that the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter will be exceeded in the Hazelwood-Braddock area. The highest calculated 24-hour concentration of 338 micrograms per cubic meter occurs at a grid point east of Braddock. Of this total, Westinghouse Electric contributes 52 percent, the U. S. Steel Homestead plant contributes 20 percent and the Jones and Laughlin plant contributes 5 percent. The highest calculated 1-hour and 3-hour concentrations in the Hazelwood-Braddock area are 1156 and 805 micrograms per cubic meter, respectively. Both maximums are located in the Hazelwood area within the isopleth for 300 micrograms per cubic meter shown in Figure 7-3. Emissions from the Bellefield Boilers account for 88 percent of the calculated 3-hour maximum, while emissions from the 12th Street Steam Plant, the Brunots Island Turbines and the Stanwix Street Steam Plant contribute 4, 3 and 3 percent, respectively. Thus, the short-term calculations indicate the SO_2 emissions for Compliance Case A will maintain the 3-hour Secondary Air Quality Standard and, depending on the ambient background, may maintain the 24-hour Primary Air Quality Standard in the Hazelwood-Braddock area.

Figure 7-4 shows, for the combined sources, the calculated isopleths of 24-hour average ground-level SO_2 concentration obtained for the Clairton-Liberty Borough area using the meteorological inputs for the Hazelwood-Braddock short-term compliance calculations. Neglecting the ambient SO_2 background, the isopleths in Figure 7-4 do not indicate that the 24-hour standard will be exceeded in the Clairton-Liberty Borough area. The grid point with the highest calculated 1-hour, 3-hour and 24-hour concentrations in this area is located on the elevated terrain east of the Clairton Coke Works. Emissions from the Clairton Coke Works account for 100 percent of the calculated maximum 1-hour, 3-hour and 24-hour concentrations of 808, 660 and 291 micrograms per cubic meter, respectively. Thus, the calculations described in this section and in Section 7.2 indicate that SO_2 emissions



PITTSBURGH
ALLEGHENY RIVER
MONONGAHELA
WILKINSBURG
SWISSVALE
CHURCHILL
MONROEVILLE
GARDEN CITY
PITCAIRN
CHALFANT
BRADDOCK
HOMESTEAD
MUNHALL
WEST MIFFLIN
EAST McKEESPORT
TRAFFORD
MT OLIVER
BRENTWOOD
1 KILOMETER
N
50
100
150
200
250
300

FIGURE 7-3. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter for the Hazelwood-Braddock area under Compliance Case A.

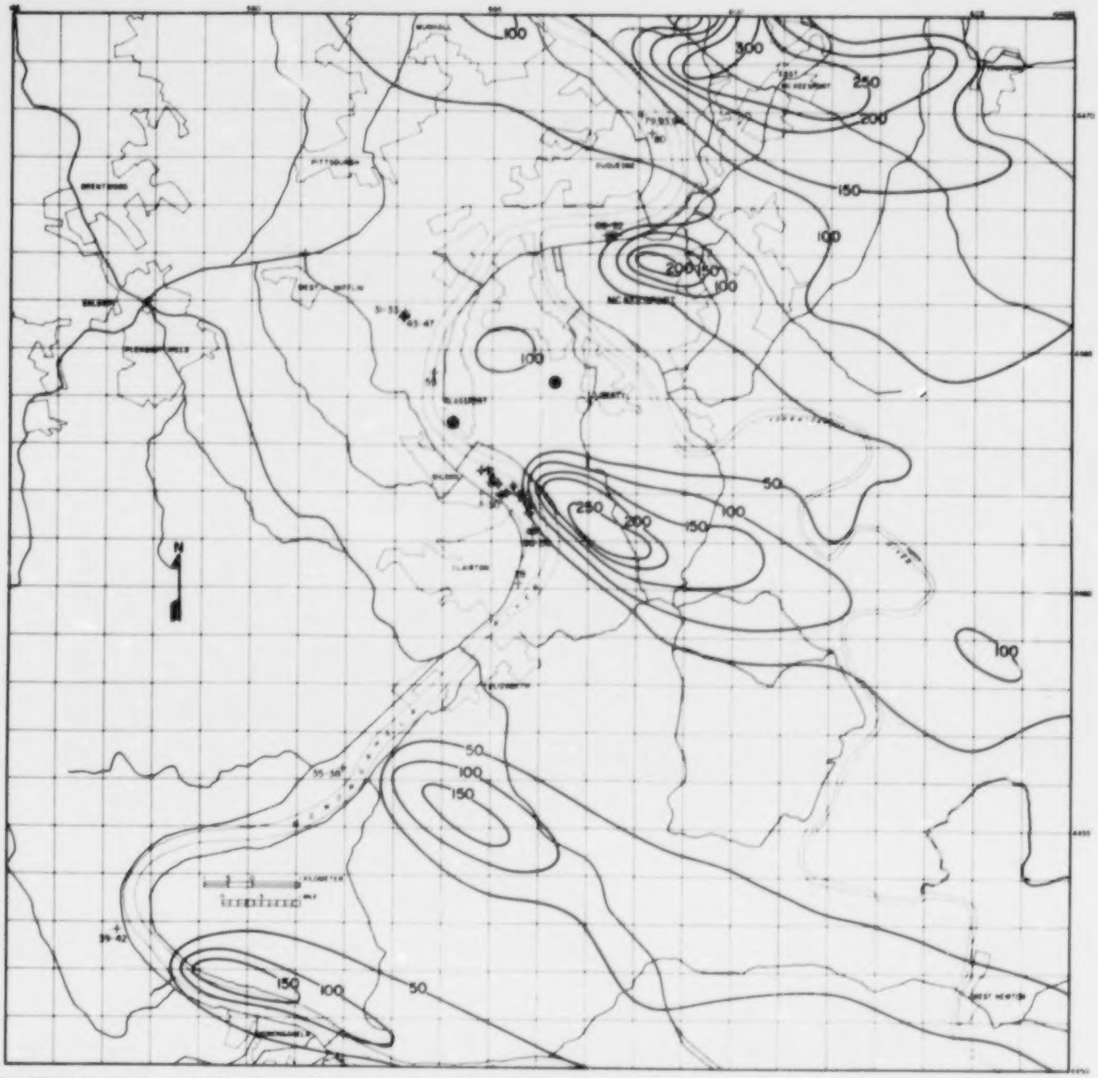

100
300
250
200
150
100
200
150
100
100
50
250
200
150
100
N
100
50
100
150
150
100
50

FIGURE 7-4. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter for the Clairton-Liberty Borough area under Compliance Case A (Hazelwood-Braddock case meteorological inputs). The two filled circles show the locations of the Glassport and Liberty Borough SO_2 monitor.

for Compliance Case A will maintain the 3-hour Secondary Air Quality Standard in the Clairton-Liberty Borough area and, if the ambient SO_2 background is less than about 55 micrograms per cubic meter, will also maintain the 24-hour Primary Air Quality Standard.

7.3.3 Source Data

Table 7-7 lists the sources, source locations, SO_2 emission rates and stack parameters used to calculate short-term ground-level SO_2 concentrations for the Hazelwood-Braddock Compliance Case A. Locations of the sources are shown in Figures 7-3 and 7-4 and on topographic maps in Figures 4-1 and 4-2. The Compliance Case A emissions data in Table 7-7 were supplied by the Allegheny County Bureau of Air Pollution Control. It should be noted that the Hazelwood-Braddock short-term compliance calculations do not consider the ambient SO_2 background or the contributions of sources other than those listed in Table 7-7.

7.3.4 Meteorological Data

Table 7-8 lists, for each hour, the wind direction, surface wind speed, mixing depth, ambient air temperature and vertical potential temperature gradient used in the calculations for the Hazelwood-Braddock compliance case. These parameters are the same as those selected for the Clairton-Liberty Borough compliance case except that west-northwest wind directions have been substituted for south-southwest winds. Tables 3-9 and 3-10 of Section 3 indicate that west-northwest winds in the 3.1- to 5.1-meter per second range persisted at the Greater Pittsburgh Airport for 12 or more hours 45 times during the 10-year period 1963 through 1972. Thus, west-northwest winds of this magnitude were assumed to persist for the first 12 hours. After the first 12 hours, the wind speed was permitted to exceed 5.1 meters per second. Because Table 3-9 shows that west-northwest winds above 3.1 meters per second persisted for 24 or more hours 8 times during the 10-year period, the wind direction was constrained within a 30-degree sector for the entire 24-hour

TABLE 7-7

SO_2 EMISSIONS, SOURCE LOCATIONS AND STACK PARAMETERS USED TO CALCULATE SHORT-TERM GROUND-LEVEL SO_2 CONCENTRATIONS FOR THE HAZELWOOD-BRADDOCK COMPLIANCE CASE A

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
1 Clairton Underfire #1	595,860	4,461,520	.33	69	700	37.27	1.220
2 Clairton Underfire #2	595,830	4,461,540	.33	69	700	37.27	1.220
3 Clairton Underfire #3	595,730	4,461,780	.33	69	700	37.27	1.220
7 Clairton Underfire #7	595,880	4,461,650	.33	65	700	35.87	1.270
8 Clairton Underfire #8	595,870	4,461,680	.33	65	700	35.87	1.270
9 Clairton Underfire #9	595,750	4,461,810	.33	65	700	35.87	1.270
10 Clairton Underfire #10	595,660	4,461,900	.33	69	700	37.27	1.220
11 Clairton Underfire #11	595,630	4,461,920	.33	69	700	37.27	1.220
12 Clairton Underfire #12	595,520	4,462,060	.33	69	700	37.27	1.220
13 Clairton Underfire #13	595,380	4,461,930	.33	69	700	37.74	1.310
14 Clairton Underfire #14	595,360	4,461,960	.33	69	700	37.74	1.310
15 Clairton Underfire #15	595,210	4,462,110	.33	69	700	37.74	1.310
16 Clairton Underfire #16	595,190	4,462,150	.33	61	700	32.13	1.310
17 Clairton Underfire #17	595,110	4,462,240	.33	61	700	32.13	1.310

TABLE 7-7 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
18 Clairton Underfire #18	595,020	4,462,330	.33	76	700	32.300	1.460
19 Clairton Underfire #19	595,280	4,461,880	.33	76	700	58.430	2.140
20 Clairton Underfire #20	595,250	4,461,910	.33	76	700	58.430	2.140
21 Clairton Underfire #21	595,060	4,462,120	.33	76	700	58.430	2.140
22 Clairton Underfire #22	595,030	4,462,160	.33	76	700	58.430	2.140
23 Clairton Underfire #12A	595,500	4,462,080	.33	69	700	35.870	1.520
24 Clairton B&W #1	595,000	4,462,470	5.65	50	455	92.570	1.370
25 Clairton CE #2	595,000	4,462,470	4.21	50	455	72.330	1.060
26 Clairton Benzene Boiler	594,870	4,462,400	1.98	52	16*	60.000*	--
27 Clairton Benzene Boiler	594,850	4,462,410	1.98	52	16*	60.000*	--
28 Clairton Blast Furnace	595,630	4,460,060	.82	60	716	180.580	1.880
30 Clairton Claus Plant	595,810	4,461,550	3.87	46	561	18.030	.610
31 Irvin 3 and 4	593,220	4,465,600	1.87	55	646	54.550	1.790
32 Irvin 5 and 6	593,230	4,465,650	2.66	78	633	79.620	1.600
33 Irvin 7	593,250	4,465,710	2.07	30	483	33.400	.920
35 Elrama	592,000	4,456,200	0	83	416	198.950	2.150

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 7-7 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
36 Elrama	592,000	4,456,200	0	83	430	198.950	2.150
37 Elrama	592,000	4,456,200	0	83	430	229.450	2.150
38 Elrama	592,000	4,456,200	35.60	89	416	299.140	2.300
39 Mitchell	587,340	4,452,810	18.33	73	403	534.810	3.050
40 Mitchell	587,340	4,452,810	5.33	70	467	223.640	2.150
41 Mitchell	587,340	4,452,810	5.33	70	467	223.640	2.150
42 Mitchell	587,340	4,452,810	5.33	70	467	223.640	2.150
43 Irvin Reheat	593,250	4,465,600	.41	52	10*	50.000*	--
44 Irvin Reheat	593,250	4,465,700	.41	52	10*	50.000*	--
45 Irvin Reheat	593,250	4,465,650	.41	52	10*	50.000*	--
46 Irvin Reheat	593,260	4,465,600	.41	52	10*	50.000*	--
47 Irvin Reheat	593,260	4,465,650	.41	52	10*	50.000*	--
48 Clairton Reheat	595,100	4,461,520	.13	52	70*	70.000*	--
49 Clairton Reheat	595,100	4,461,530	.13	52	70*	70.000*	--
50 Clairton Reheat	595,100	4,461,540	.13	52	70*	70.000*	--
51 Clairton Reheat	595,100	4,461,500	.13	52	70*	70.000*	--

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 7-7 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
52 Clairton Reheat	595,100	4,461,560	.13	52	70	70.000	--
53 Clairton Reheat	595,100	4,461,570	.13	52	70	70.000	--
54 Clairton Reheat	595,100	4,461,580	.13	52	70	70.000	--
55 Pitron	593,850	4,464,500	.11	75	600	88.000	2.000
60 Phillips Power Station	565,260	4,491,020	0	76	461	83.460	1.800
61 Phillips Power Station	565,260	4,491,020	0	76	461	83.460	1.800
62 Phillips Power Station	565,260	4,491,020	0	76	457	118.070	1.800
63 Phillips Power Station	565,260	4,491,020	0	76	457	118.070	1.800
64 Phillips Power Station	565,260	4,491,020	32.13	76	457	118.070	1.800
65 Phillips Power Station	565,260	4,491,020	0	49	430	167.850	2.300
66 Brunots Island Turbines	580,680	4,479,680	2.81	10	735	237.600	.900
67 Brunots Island Turbines	580,730	4,479,720	2.81	10	735	237.600	.900
68 Brunots Island Turbines	580,770	4,479,750	2.81	10	735	237.600	.900
69 12th Street Steam	585,200	4,477,600	5.36	82	604	108.260	2.000
70 Stanwix Street Steam	584,380	4,477,300	7.12	112	574	227.230	2.600
71 H. J. Heinz Co.	586,000	4,478,900	1.97	76	473	18.730	1.500

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 7-7 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
72 H. J. Heinz Co.	586,000	4,478,900	2.67	76	473	16.290	1.500
73 Westinghouse Electric	599,020	4,472,550	3.91	50	505	17.420	1.100
74 Westinghouse Electric	599,020	4,472,550	3.05	37	461	7.470	1.000
75 Bellefield Boilers	589,190	4,477,100	2.37	59	589	26.950	1.400
76 Bellefield Boilers	589,190	4,477,100	3.05	69	561	24.150	1.700
77 Pittsburgh Brewery	587,550	4,479,280	1.28	63	472	39.560	1.200
78 WABCO	594,400	4,475,550	1.59	27	569	19.310	.700
79 Duquesne N C Boilers	598,120	4,469,830	.24	49	551	32.870	1.100
80 Duquesne Reheat	598,360	4,469,450	.94	37	700	26.300	.900
81 E. T. N C Boilers	597,110	4,471,610	.12	33	551	26.230	1.200
82 E. T. Soaking Pits	597,440	4,471,870	.63	30	764	22.320	.800
83 Homestead N C Boilers	592,850	4,473,830	.02	16	361	25.040	1.600
84 Homestead Process 1	593,400	4,473,870	1.22	32	50*	100.000	--
85 Homestead Process 2	591,900	4,473,400	1.22	32	50*	100.000	--
86 Homestead Process 3	593,150	4,473,850	1.22	32	50*	100.000	--
87 Homestead #5 OH	592,350	4,473,750	4.15	38	532	153.930	2.000

*Indicates building source; building length and width are entered as Stack Temperature and Volume.

TABLE 7-7 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (°K)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
88 National #1	597,400	4,467,330	2.06	46	590	39.250	1.300
89 National #2	597,450	4,467,330	2.06	46	590	39.250	1.300
90 National #3	597,500	4,467,330	2.06	46	590	39.250	1.300
91 National #4	597,550	4,467,330	2.06	46	590	39.250	1.300
92 National #5	597,600	4,467,330	2.06	46	590	39.250	1.300
93 Duquesne #15	598,120	4,469,830	1.30	49	551	32.870	1.100
94 Duquesne #17	598,120	4,469,830	1.30	49	551	32.870	1.100
95 E. T. #1	596,990	4,471,670	3.85	50	533	121.550	2.100
96 E. T. #2	596,990	4,471,670	3.85	50	533	121.550	2.100
97 E. T. #3	596,990	4,471,670	3.85	50	533	121.550	2.100
98 Homestead Carrie #3	594,120	4,474,020	5.38	43	561	200.320	2.400
99 Homestead Carrie #4	594,120	4,474,020	4.35	43	561	154.030	1.900
100 Mesta Machine Co.	590,920	4,471,980	1.40	61	511	7.360	.900
101 J & L By Products Boilers	589,250	4,473,900	1.06	24.4	616	6.150	.680
102 J & L Eliza Boilers	588,560	4,475,400	.18	36.6	477	66.630	1.340
103 J & L South Side Boilers	588,030	4,475,280	4.39	35.7	477	26.650	1.220

TABLE 7-7 (Continued)

Source	Location (UTM)		SO_2 Emissions (tons/day)	Stack Height (m)	Stack Exit Temperature (^oK)	Actual Stack Gas Volume (m^3/sec)	Stack Inner Radius (m)
	X Coordinate	Y Coordinate					
104 J & L Underfire #1	589, 150	4, 474, 030	.14	61	600	32. 140	1.300
105 J & L Underfire #2	589, 150	4, 474, 020	.14	62.6	600	31. 700	1.450
106 J & L Underfire #3	589, 190	4, 473, 860	.14	62.6	600	31. 700	1.450
107 J & L Underfire #4	589, 190	4, 473, 840	.14	62.6	600	31. 700	1.450
108 J & L Underfire #5	589, 200	4, 473, 750	.21	62.6	600	31. 700	1.450
109 J & L Open Hearth	587, 850	4, 475, 680	5.00	38	532	153. 950	1.980
110 J & L Barmill #1	589, 240	4, 474, 060	.23	38.1	727	20. 400	.840
111 J & L Barmill #2	589, 260	4, 474, 150	.11	38.1	727	24. 900	1.070
112 J & L Stripmill	588, 265	4, 475, 775	.19	18.0	727	47. 420	1.300
113 J & L Soaking Pits	587, 780	4, 475, 470	.26	48	727	4. 850	.860
114 J & L Soaking Pits	587, 800	4, 475, 550	.24	34	727	2. 920	.780
115 J & L Claus Plant	587, 190	4, 474, 000	1.90	46	977	24. 63	.700

TABLE 7-8

METEOROLOGICAL INPUT PARAMETERS FOR THE HAZELWOOD-BRADDOCK COMPLIANCE CASE A CALCULATIONS

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	290	3.6	125	273	0.021	D
02	285	3.6	125	273	0.021	D
03	295	4.1	125	273	0.021	D
04	290	3.6	125	273	0.021	D
05	290	4.6	125	273	0.021	D
06	290	3.6	125	273	0.021	D
07	300	4.1	125	273	0.021	D
08	305	4.1	125	273	0.018	
09	295	4.6	125	273	0.014	D
10	290	4.6	125	273	0.011	D
11	300	5.1	150	273	0.007	D
12	305	5.1	200	273	0.003	D
13	295	7.2	250	273	0.003	D
14	285	6.2	300	273	0.003	D
15	275	6.2	180	273	0.007	D
16	275	5.7	125	273	0.010	D
17	275	5.1	125	273	0.014	D
18	285	4.1	125	273	0.017	D
19	290	3.6	125	273	0.021	D
20	305	4.6	125	273	0.021	D
21	310	3.6	125	273	0.021	D
22	290	4.1	125	273	0.021	D
23	280	3.6	125	273	0.021	D
24	275	3.6	125	273	0.021	D

period. The mixing depths and vertical potential temperature gradients listed in Table 7-8 are similar to those observed during the air pollution episode of 18 January 1973 (see Section 6.2). The wind-profile exponent was set equal to the value of 0.25 derived from vertical wind profiles on 18 January 1973. Because it is assumed in the compliance calculations that broken to overcast skies persist throughout the 24-hour period, the lateral and vertical turbulent intensities were set equal to the urban values for Pasquill stability category D of 0.1051 and 0.0735 radians, respectively (see Table 3-5).

SECTION 8

SUMMARY OF THE LONG-TERM AND SHORT-TERM CONCENTRATION CALCULATIONS

8.1 RESULTS OF 1973 CONCENTRATION CALCULATIONS AND COMPARISON WITH OBSERVED AIR QUALITY DATA

The performance of the long-term and short-term diffusion models described in Appendix A was tested by calculating the annual average ground-level SO_2 concentrations in Allegheny County for 1973, as well as 3-hour and 24-hour maximums for three selected cases in 1973, for comparison with observed air quality at three continuous SO_2 monitors operated by the Allegheny County Bureau of Air Pollution Control. Table 8-1 lists the calculated and observed ground-level SO_2 concentrations for each of the 1973 cases studied. As shown by the table, the calculated 3-hour concentrations are, on the average, about 14 percent higher than the measured concentrations, while the calculated 24-hour concentrations are about 83 percent of the measured concentrations. The poorest correspondence between calculated and observed 3-hour and 24-hour concentrations is the 18 January 1973 case for the Liberty Borough monitor. As explained in Section 6.2, changes of 10 to 20 degrees in the hourly wind directions used in the calculations would bring both the 3-hour and 24-hour calculated and observed concentrations into close agreement. Table 8-1 also shows that the calculated annual average ground-level SO_2 concentrations are, on the average, about 92 percent of the observed concentrations. Because the ambient SO_2 background was not included in either the short-term or the long-term calculations, the calculated concentrations are expected to be lower than the observed concentrations.

The annual average concentration calculations for the year 1973 indicate that the annual Primary Air Quality Standard of 80 micrograms per cubic meter was exceeded over an area of approximately 120 square kilometers extending about

TABLE 8-1

COMPARISON OF CALCULATED AND OBSERVED 1973 GROUND-LEVEL SO_2 CONCENTRATIONS

Case	Monitor Location	SO_2 Concentration ($\mu g/m^3$)		Calculated Concentration / Observed Concentration
		Calculated	Observed	
(a) 3-Hour Maximum Concentration				
4 January 1973	Logans Ferry	2207	1880	1.17
18 January 1973	Glassport	375	300	1.25
18 January 1973	Liberty Borough	717	1305	0.55
13 July 1973	Glassport	496	395	1.26
13 July 1973	Liberty Borough	1204	820	1.47
			Mean Ratio	1.14
(b) 24-Hour Average Concentration				
4 January 1973	Logans Ferry	979	891	1.10
18 January 1973	Glassport	186	153	1.22
18 January 1973	Liberty Borough	268	647	0.41
13 July 1973	Glassport	101	139	0.73
13 July 1973	Liberty Borough	258	361	0.71
			Mean Ratio	0.83
(c) Annual Average Concentration				
1973	Glassport	80	79	1.01
1973	Liberty Borough	116	139	0.83
			Mean Ratio	0.92

3 kilometers on both sides of the Monongahela River from the southern boundary of Allegheny County north to the junction of the Monongahela and Youghiogheny River. Within this large area there are four subareas (hotspots) in which the calculated concentrations exceed the annual standard by a factor of two or more. Two of these hotspots are almost exclusively the result of emissions from the Elrama and Mitchell power plants; one is located approximately 2.5 kilometers northeast of the Elrama power plant on the east side of the Monongahela River while the other is located approximately 2.5 kilometers directly north of the Elrama power plant. A third hotspot, located in Clairton on the west side of the Monongahela River approximately 1 kilometer west of the center of the Clairton Coke Works, is principally caused by emissions from the Clairton Coke Works, plus contributions from the Elrama and Mitchell power plants. The fourth hotspot covers an area of about 10 square kilometers centered approximately 1 kilometer north and northeast of the Clairton Coke Works on the west side of the Monongahela River in the Glassport-Liberty Borough area. Within this 10-square kilometer area, emissions from the Clairton Coke Works contribute from 60 to 90 percent of the total calculated annual average, the Elrama power plant emissions from 6 to 20 percent and the Mitchell power plant emissions contribute 2 to 8 percent, depending on the point of interest.

The annual average concentration calculations for 1973 also indicate that ground-level SO_2 concentrations greater than the annual standard occurred over an area of about 40 square kilometers located along, and mostly on the north side of, the Monongahela River starting just east of the Jones and Laughlin Pittsburgh plant and extending upriver to the U. S. Steel Homestead plant. Within this large area there are two hotspots in which the calculated concentrations exceed the annual standard by a factor of two or more. One of these hotspots is located on the north side of the Monongahela River directly opposite the Jones and Laughlin Pittsburgh plant, which contributes about 85 percent of the total calculated annual average SO_2 concentration at this spot.

The short-term concentration calculations for the 4 January 1973 air pollution episode at Logans Ferry show that both the 3-hour Secondary Air Quality Standard of 1300 micrograms per cubic meter and the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter were exceeded within an area of about 1 square kilometer centered on the Logans Ferry monitor. According to the calculations, emissions from the West Penn power plant accounted for about 97 percent of both maximums, with the remaining 3 percent contributed by emissions from the Cheswick plant.

The short-term calculations for the 18 January 1973 air pollution episode at Liberty Borough show that the 24-hour standard was exceeded in three separate areas. In one area approximately 2.2 kilometers north of the Elrama power plant, the calculated maximum 24-hour concentration is 457 micrograms per cubic meter of which the Elrama power plant contributed 89 percent and the Mitchell power plant contributed the remaining 11 percent. In a second area approximately 0.5 kilometers north of the Irvin plant, the calculated maximum 24-hour concentration is 579 micrograms per cubic meter of which the Irvin plant contributed 54 percent, the Clairton Coke Works 27 percent, the Elrama power plant 16 percent and the Mitchell power plant 3 percent. In a third area approximately 1.2 kilometers north of the Clairton Coke Works, the calculated maximum 24-hour concentration is 472 micrograms per cubic meter of which the Clairton Coke Works contributed 88 percent and the Elrama power plant contributed 11 percent. Average 24-hour concentrations approaching the 24-hour standard were also calculated in an area about 7.5 kilometers northwest of the Elrama power plant and were produced by emissions from the Elrama and Mitchell power plants.

The short-term model calculations for the 13 July 1973 air pollution episode at Liberty Borough indicate that the 24-hour standard was exceeded in two areas. One of these areas is located approximately 3 kilometers northeast of the Elrama power plant along the Monongahela River west of the town of Elizabeth; Elrama emissions account for 95 percent of the calculated concentration of 450 micrograms per cubic meter and Mitchell emissions account for the remaining 5 percent. The second area of high SO_2 concentrations is located on the east side of the Monongahela River approximately 1.5 kilometers northeast of the Clairton Coke Works. Of the calculated concentration of 842 micrograms per cubic meter, emissions from the Clairton Coke Works account for 9 percent of the total and the Mitchell power plant contributes 3 percent.

Table 8-2 lists, for the major source complexes and for the combined sources, the 1973 24-hour and annual average ground-level SO_2 concentrations calculated at the Glassport and Liberty Borough monitors. Table 8-2 also gives the individual source contributions to the calculated maximum concentrations in the Clairton-Liberty Borough area.

It should be noted that, in contrast to the usual practice, no use was made of calibration constants to scale calculated concentrations to air quality observations. The calculated concentrations presented in this report were directly obtained from the supplied source and meteorological data. On the basis of the correspondence between the calculated and observed concentrations shown in Table 8-1, we conclude that both the long-term and short-term diffusion models provide a satisfactory representation of the transport and diffusion of emissions from the major SO_2 sources in Allegheny County.

8.2 RESULTS OF COMPLIANCE CASE CALCULATIONS

Calculations using the long-term diffusion model and the projected SO_2 emissions for the compliance case (see Section 5.1) indicate that the annual Primary Air Quality Standard of 80 micrograms per cubic meter will be exceeded in the area between Clairton, Glassport and Liberty Borough and in an area of several square kilometers located east of Braddock. Calculations using the short-term diffusion model and projected SO_2 emissions indicate that the 24-hour Primary Air Quality Standard of 365 micrograms per cubic meter will be exceeded in a small area in

TABLE 8-2

ANNUAL AND 24-HOUR AVERAGE GROUND-LEVEL SO_2 CONCENTRATIONS CALCULATED FOR THE CLAIRTON-LIBERTY BOROUGH AREA DURING 1973

Source	Concentration ($\mu g/m^3$)		
	Glassport Monitor	Liberty Borough Monitor	Calculated Maximum
(a) 18 January 1973			
Clairton	93 (50%)	188 (70%)	156 (27%)
Irvin	0 (0%)	0 (0%)	311 (54%)
Elrama	84 (45%)	72 (27%)	92 (16%)
Mitchell	9 (5%)	8 (3%)	19 (3%)
Combined Sources	186 (100%)	268 (100%)	579 (100%)
(b) 13 July 1973			
Clairton	0 (0%)	144 (56%)	739 (88%)
Irvin	0 (0%)	0 (0%)	0 (0%)
Elrama	89 (88%)	105 (41%)	78 (9%)
Mitchell	12 (12%)	9 (3%)	25 (3%)
Combined Sources	101 (100%)	258 (100%)	842 (100%)
(c) 1973 Annual			
Clairton	49 (61%)	88 (76%)	301 (90%)
Irvin	4 (5%)	3 (3%)	1 (0%)
Elrama	16 (20%)	14 (12%)	19 (6%)
Mitchell	6 (8%)	6 (5%)	7 (2%)
Others	5 (6%)	5 (4%)	5 (2%)
Combined Sources	80 (100%)	116 (100%)	333 (100%)

the vicinity of the Logans Ferry SO_2 monitor and, depending on the ambient background assigned, may be exceeded in the Clairton-Liberty Borough area and in a small area east of Braddock. The calculations for Compliance Case A indicate that the 3-hour Secondary Air Quality Standard will not be exceeded. Table 8-3 lists the individual contributions of major SO_2 source complexes to the maximum 3-hour, 24-hour and annual average ground-level SO_2 concentrations calculated in the Clairton-Liberty Borough and Hazelwood-Braddock areas. In the Logans Ferry area, emissions from the West Penn power plant account for about 97 percent of the calculated maximum 3-hour and 24-hour concentrations of 748 and 458 micrograms per cubic meter, respectively.

TABLE 8-3

CALCULATED MAXIMUM 3-HOUR, 24-HOUR AND ANNUAL AVERAGE CONCENTRATIONS IN THE CLAIRTON-LIBERTY BOROUGH AND HAZELWOOD-BRADDOCK AREAS FOR THE COMPLIANCE CASE

Source	Maximum Concentration ($\mu g/m^3$)		
	3-Hour	24-Hour	Annual
(a) Clairton-Liberty Borough Area			
Clairton	0 (0%)	212 (68%)	102 (85%)
Irvin	0 (0%)	0 (0%)	2 (2%)
Elrama	0 (0%)	70 (23%)	4 (3%)
Mitchell	699 (100%)	28 (9%)	2 (2%)
Others	0 (0%)	0 (0%)	10 (8%)
Combined Sources	699 (100%)	310 (100%)	120 (100%)
(b) Hazelwood-Braddock Area			
Homestead	0 (0%)	69 (20%)	5 (3%)
Westinghouse Electric	0 (0%)	176 (52%)	125 (80%)
Bellefield Boiler	711 (88%)	10 (3%)	1 (1%)
Jones and Laughlin	0 (0%)	17 (5%)	1 (1%)
Edgar Thomson	0 (0%)	2 (1%)	11 (7%)
Others	94 (12%)	64 (19%)	13 (8%)
Combined Sources	805 (100%)	338 (100%)	156 (100%)

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APPENDIX A

MATHEMATICAL MODELS USED TO CALCULATE GROUND-LEVEL CONCENTRATIONS

A.1 INTRODUCTION

The computerized diffusion models described in this appendix fall into two general categories: (1) Short-term models for calculating time-averaged ground-level concentrations for averaging times of 1, 3, 8 and 24 hours; (2) Long-term models for calculating seasonal and annual ground-level concentrations. Both the short-term and the long-term concentration models are modified versions of the Gaussian plume model for continuous sources described by Pasquill (1962). In the short-term model, the plume is assumed to have Gaussian vertical and lateral concentration distributions. The long-term model is a sector model similar in form to the Environmental Protection Agency's Climatological Dispersion Model (Calder, 1971) in which the vertical concentration distribution is assumed to be Gaussian and the lateral concentration distribution within a sector is rectangular (a smoothing function is used to eliminate sharp discontinuities at the sector boundaries). The σ_z vertical expansion curves and the σ_y lateral expansion curves are determined by using turbulent intensities in simple power law expressions that include the effects of initial source dimensions. In both the short-term and long-term models, buoyant plume rise is calculated by means of the Briggs (1971) plume-rise formulas. An exponent law is used to adjust the surface wind speed to the source height for plume-rise calculations and to the plume stabilization height for concentration calculations. Both the short-term and the long-term models contain provisions to account for the effects of complex terrain.

Table A-1 lists the hourly meteorological inputs required by the short-term concentration model. Lateral and vertical turbulent intensities σ'_A and σ'_E

TABLE A-1

HOURLY METEOROLOGICAL INPUTS REQUIRED BY THE SHORT-TERM CONCENTRATION MODEL

Parameter	Definition
$\bar{u}_R$	Mean wind speed at height z_R
θ	Mean wind direction at height z_R
p	Wind-profile exponent
σ'_A	Wind azimuth-angle standard deviation in radians
σ'_E	Wind elevation-angle standard deviation in radians
T_a	Ambient air temperature (^{o}K)
H_m	Depth of surface mixing layer
$\frac{\partial \theta}{\partial z}$	Vertical potential temperature gradient

may be directly specified or may be assigned on the basis of the Pasquill stability category. The Pasquill stability category is determined from surface weather observations using the Turner (1964) wind-speed and solar-index values. Mixing depths may be obtained from rawinsonde or pibal measurements, or they may be assigned on the basis of tabulations of the frequency of occurrence of wind speed and mixing depth (available from the National Climatic Center for synoptic rawinsonde stations). Potential temperature gradients may be measured or assigned on the basis of climatology.

Table A-2 lists the meteorological inputs required by the long-term concentration model. Joint-frequency distributions of wind-speed and wind-direction categories according to the Pasquill stability categories may be obtained from the National Climatic Center. Alternately, surface wind observations may be analyzed to generate wind-frequency distributions by time-of-day categories (night, morning, afternoon and evening). Vertical turbulent intensities may be determined from a climatology of actual measurements or may be assigned on the basis of the Pasquill stability categories. Median mixing depths may be determined from the seasonal tabulations of the frequency of occurrence of wind speed and mixing depth. Vertical potential temperature gradients may be assigned to stability or time-of-day categories on the basis of climatology.

We point out that the model descriptions contained in this appendix are comprehensive and in some instances contain features that were not used in this study. For example, the area source models described in Sections A.3.3 and A.4.3 were not used. Also, the decay constant ψ was set equal to zero for both the short-term and long-term concentration calculations.

TABLE A-2

METEOROLOGICAL INPUTS REQUIRED BY THE LONG-TERM CONCENTRATION MODEL

Parameter	Definition
$f_{i,j,k,\ell}$ (Table)	Frequency distribution of wind-speed and wind-direction categories by stability or time-of-day categories for the ℓ^{th} season
z_R	Height at which wind-frequency distributions were obtained
$p_{k,i}$ (Table)	Wind-profile exponents for each stability or time-of-day category and i^{th} wind speed category
$\sigma'_{E;i,k}$ (Table)	Standard deviation of the wind elevation angle in radians for the i^{th} wind-speed category and k^{th} stability or time-of-day category and ℓ^{th} season
$T_{a;k,\ell}$ (Table)	Ambient air temperature for the k^{th} stability or time-of-day category and ℓ^{th} season
$\left(\frac{\partial\theta}{\partial z}\right)_{i,k}$ (Table)	Vertical potential temperature gradient for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$H_{m;i,k,\ell}$ (Table)	Median surface mixing depth for the i^{th} wind-speed category, k^{th} stability or time-of-day category and ℓ^{th} season
$\bar{u}\{z_R\}_i$ (Table)	Mean wind speeds at height z_R

A.2 PLUME RISE FORMULAS

The effective stack height H of a buoyant plume is given by the sum of the physical stack height h and the bouyant rise Δh. For an adiabatic or unstable atmosphere, the buoyant rise Δh_N is given by

$$\Delta h_N = \left[\frac{1}{\bar{u}\{h\}} \left(\frac{3F}{2\gamma_1^2} \right)^{1/3} \left(10h\right)^{2/3} \right] f \tag{1}$$

where the expression in the brackets is from Briggs (1971; 1972) and

$\bar{u}\{h\}$ = the mean wind speed at the stack height h

γ_1 = the adiabatic entrainment coefficient ~0.6

F = the initial buoyancy flux

$$= \frac{gV}{\pi} \left(1 - \frac{T_a}{T_s} \right) \tag{2}$$

V = the volumetric emission rate of the stack

$= \pi r^2 w$

r = inner radius of stack

w = stack exit velocity

g = the acceleration due to gravity

T_a = the ambient air temperature (°K)

T_s = the stack exit temperature (°K)

The factor f, which limits the plume rise as the mean wind speed at stack height approaches or exceeds the stack exit velocity, is defined by

$$f = \left\{ \begin{array}{ll} 1 & ;\ u\{h\} \le w/1.5 \\ \left(\dfrac{3w - 3\bar{u}\{h\}}{w}\right) & ;\ w/1.5 < u\{h\} < w \\ 0 & ;\ u\{h\} \ge w \end{array} \right\} \qquad (3)$$

The corresponding Briggs (1971) rise formula for a stable atmosphere (potential temperature gradient greater than zero) is

$$\Delta h_S = \left\{ \begin{array}{ll} \left[\dfrac{6F}{\bar{u}\{h\}\gamma_2^2 S}\right]^{1/3} & ;\ \pi\,\bar{u}\{h\}\,S^{-1/2} < 10h \\ \left[\dfrac{3F}{\bar{u}\{h\}\gamma_2^2 S}\left(1 - \cos\left(\dfrac{10S^{1/2}h}{\bar{u}\{h\}}\right)\right)\right]^{1/3} & ;\ \pi\,\bar{u}\{h\}\,S^{-1/2} \ge 10h \end{array} \right\} f \qquad (4)$$

where

γ_2 = the stable entrainment coefficient ~ 0.66

$S = \dfrac{g}{T_a}\dfrac{\partial\theta}{\partial z}$

$\dfrac{\partial\theta}{\partial z}$ = vertical potential temperature gradient

The entrainment coefficients γ_1 and γ_2 are based on the suggestions of Briggs (1972). It should be noted that Equation (4) does not permit the calculated stable rise Δh_s to exceed the adiabatic rise Δh_N as the atmosphere approaches a neutral stratification $\left(\frac{\partial\theta}{\partial z}\text{ approaches } 0\right)$. A procedure of this type is recommended by Briggs (1972).

A.3 SHORT-TERM CONCENTRATION MODEL

A.3.1 Elevated Sources

The atmospheric dispersion model used to calculate hourly average ground-level concentrations downwind from an elevated continuous source is given by

$$\chi\{x,y\} = \frac{K\,Q}{\pi\,\bar{u}\{H\}\,\sigma_y\,\sigma_z}\ \{\text{Vertical Term}\}\ \{\text{Lateral Term}\}\ \{\text{Decay Term}\} \qquad (5)$$

where

K = scaling coefficient to convert input parameters to dimensionally consistent units

Q = source emission rate

$\bar{u}\{H\}$ = mean wind speed at the plume stabilization height H

σ_y, σ_z = standard deviations of the lateral and vertical concentration distributions at downwind distance x

The Vertical Term refers to the plume expansion in the vertical or z direction and includes a multiple reflection term that limits cloud growth to the surface mixing layer.

$$\{\text{Vertical Term}\} = \left\{ \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] + \sum_{n=1}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2n\,H_m + H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2n\,H_m - H}{\sigma_z}\right)^2\right]\right]\right\} \qquad (6)$$

where H_m is the depth of the surface mixing layer. The exponential terms in the infinite series in Equation (6) rapidly approach zero near the source. At the downwind distance at which the exponential terms are non-zero for n equal 3, the plume has become approximately uniformly mixed within the surface mixing layer. In order to shorten computer computation time, Equation (6) is changed to the form

$$\{\text{Vertical Term}\} = \frac{\sqrt{2\pi}\ \sigma_z}{2\ H_m} \tag{7}$$

beyond this point. Equation (7) changes the form of the vertical concentration distribution from Gaussian to rectangular. If H exceeds H_m, the vertical term is set equal to zero which results in a zero value for the ground-level concentration.

The Lateral Term refers to the crosswind expansion of the plume and is given by the expression

$$\{\text{Lateral Term}\} = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \tag{8}$$

where y is the crosswind distance from the plume centerline to the point at which concentration is calculated.

The Decay Term, which accounts for the possibility of pollutant removal by physical or chemical processes, is of the form

$$\{\text{Decay Term}\} = \exp\left[-\psi\, x/\bar{u}\ \{H\}\right] \tag{9}$$

where

ψ = the washout coefficient Λ ($\sec^{-1}$) for precipitation scavenging

= $\frac{0.692}{T_{1/2}}$, where $T_{1/2}$ is the pollutant half life for physical or chemical removal

= 0 for no depletion (ψ is automatically set to zero by the computer program unless otherwise specified)

In the model calculations, the observed mean wind speed $\bar{u}_R$ is adjusted from the measurement height z_R to the source height h for plume rise calculations and to the stabilization height H for the concentration calculations by a wind-profile exponent law

$$\bar{u}\{z\} = \bar{u}\{z_R\} \left(\frac{z}{z_R}\right)^p \tag{10}$$

The exponent p is assigned on the basis of atmospheric stability, ranging from about 0.1 for very unstable conditions to about 0.4 for very stable conditions.

According to the derivation in the report by Cramer, et al, (1972), the standard derivation of the lateral concentration distribution σ_y is given by the expression

$$\sigma_y\{x\} = \sigma'_A \, x_{ry} \left[\frac{x + x_y - x_{ry}(1 - \alpha)}{\alpha x_{ry}}\right]^{\alpha} \tag{11}$$

$$x_y = \left\{\begin{array}{ll} \dfrac{\sigma_{yR}}{\sigma'_A} - x_R & ; \quad \dfrac{\sigma_{yR}}{\sigma'_A} \leq x_{ry} \\ \alpha x_{ry}\left(\dfrac{\sigma_{yR}}{x_{ry}\,\sigma'_A}\right)^{1/\alpha} - x_R + x_{ry}\,(1 - \alpha); & \dfrac{\sigma_{yR}}{\sigma'_A} > x_{ry} \end{array}\right\} \tag{12}$$

where

σ'_A = the standard deviation of the wind-azimuth angle in radians

x_{ry} = distance over which rectilinear plume expansion occurs downwind from an ideal point source (~ 50 meters)

σ_{yR} = the standard deviation of the lateral concentration distribution at downwind distance x_R

α = the lateral diffusion coefficient (~ 0.9)

The lateral turbulent intensity σ'_A may be specified directly or may be assigned on the basis of the Pasquill stability category.

The standard deviation of the vertical concentration distribution σ_z is given by the expression

$$\sigma_z(x) = \sigma'_E (x + x_z) \qquad (13)$$

$$x_z = \begin{cases} \dfrac{\sigma_{zR}}{\sigma'_E} - x_R \; ; & \dfrac{\sigma_{zR}}{\sigma'_E} \geq x_R \\ 0 \; ; & \dfrac{\sigma_{zR}}{\sigma'_E} < x_R \end{cases} \qquad (14)$$

where

σ'_E = standard deviation of the wind-elevation angle in radians

σ_{zR} = the standard deviation of the vertical concentration distribution at downwind distance x_R

The vertical turbulent intensity σ'_E may also be obtained from direct measurements or may be assigned according to Pasquill stability category. When σ'_E values corresponding to the Pasquill stability categories are entered in Equation (13), the resulting curves will differ from the corresponding Pasquill-Gifford curves in that Equation (13) assumes rectilinear expansion at all downwind distances. Thus, σ_z values obtained from Equation (13) will be smaller than the values obtained from the Pasquill-Gifford A and B curves and larger than the values obtained from the D, E and F curves at long downwind distances. However, the multiple reflection term in Equation (6) which confines the plume to the surface mixing layer accounts for the behavior of the D, E and F curves (decrease in the expansion rate with distance) in a manner that may be related to the meteorology of the area.

Following the recommendations of Briggs (1972), the lateral and vertical standard deviations of a stabilized buoyant plume are defined by

$$\sigma_{yR} = \sigma_{zR} = \frac{0.5\ \Delta h}{2.15} \tag{15}$$

The downwind distance to stabilization x_R is given by

$$x_R = \left\{ \begin{array}{ll} 10h & ; \frac{\partial \theta}{\partial z} \leq 0 \\ \pi \bar{u}\{h\}\ S^{-1/2} & ; \frac{\partial \theta}{\partial z} > 0 \text{ and } \pi \bar{u}\{h\}\ S^{-1/2} < 10h \\ 10h & ; \frac{\partial \theta}{\partial z} > 0 \text{ and } \pi \bar{u}\{h\}\ S^{-1/2} \geq 10h \end{array} \right\} \tag{16}$$

A. 3. 2 Application of the Short-Term Model to Low-Level Emissions

The short-term diffusion model in Section A. 3. 1 may be used to calculate ground-level concentrations resulting from low-level emissions such as losses through building vents. These emissions are rapidly distributed by the cavity circulation of the building wake and quickly assume the dimensions of the building. Ground-level concentrations are calculated by setting the release height h and the buoyancy parameter F equal to zero. The standard deviation of the lateral concentration distribution at the source σ_{yo} is defined by the building crosswind dimension y_o divided by 4.3. The standard deviation of the vertical concentration distribution at the source σ_{zo} is obtained by dividing the building height by 2.15. The initial dimensions σ_{yo} and σ_{zo} are assumed to be applicable at the downwind edge of the building. It should be noted that separate turbulent intensities σ'_A and σ'_E may be defined for the low-level sources to account for the effects of surface roughness elements and heat sources.

A.3.3 Short-Term Concentration Model for Area Sources

The atmospheric dispersion model used to calculate ground-level concentrations at downwind distance x from the downwind edge of an area source is given by the expression

$$\chi\{x > x_o, y\} = \frac{K\,Q}{\sqrt{2\pi}\,\bar{u}\{h\}\,\sigma_z\{x\}\,y_o}\,\{\text{Vertical Term}\}\,\{\text{Lateral Term}\}\,\{\text{Decay Term}\} \qquad (17)$$

where

Q = area source strength in units of mass per unit time

y_o = crosswind source dimension

$$\sigma_z\{x\} = \left\{ \begin{array}{ll} \dfrac{\sigma'_E\, x_o}{\ell_n \left[\dfrac{\sigma'_E\,(x + x_o) + h}{\sigma'_E\,(x) + h} \right]} & ;\ x < 3x_o \\ \\ \sigma'_E\,(x + x_o/2) + h & ;\ x \geq 3x_o \end{array} \right\} \qquad (18)$$

x_o = alongwind dimension of the area source

h = the characteristic height of the area source

The Vertical Term for an area source is given by

$$\{\text{Vertical Term}\} = \begin{cases} 1 + 2\displaystyle\sum_{n=1}^{3} \left\{ \exp\left[-\frac{1}{2}\left(\frac{2n\,H_m}{\sigma_z\{x\}}\right)^2 \right] \right\} & ;\ \exp\left[-\frac{1}{2}\left(\frac{6H_m}{\sigma_z}\right)^2 \right] = 0 \\ \dfrac{\sqrt{2\pi}\,\sigma_z\{x\}}{2H_m} & ;\ \exp\left[-\frac{1}{2}\left(\frac{6H_m}{\sigma_z}\right)^2 \right] > 0 \end{cases} \tag{19}$$

The Lateral Term is given by the expression

$$\{\text{Lateral Term}\} = \left\{ \mathrm{erf}\left[\frac{y_o/2 + y}{\sqrt{2}\,\sigma_y\{x\}}\right] + \mathrm{erf}\left[\frac{y_o/2 - y}{\sqrt{2}\,\sigma_y\{x\}}\right] \right\} \tag{20}$$

where

y_o = crosswind dimension of the area source

y = crosswind distance from the centerline of the area source

and

$$\sigma_y\{x\} = \sigma_A'(x + x_o/2) \tag{21}$$

The Decay Term is given by Equation (9) above.

The concentration at points interior to the area source is given by

$$\chi\{x'\} = \frac{2K\,Q}{\sqrt{2\pi}\,\bar{u}\{h\}\,x_o\,y_o\,\sigma_E'} \left\{ \ln\left[\frac{\sigma_E'(x' + 1) + h}{\sigma_E' + h} \right] \right\} \{\text{Vertical Term}\} \tag{22}$$

where

x' = distance downwind from the upwind edge of the area source

A.4 LONG-TERM CONCENTRATION MODEL

A.4.1 Elevated Sources

The atmospheric dispersion model for elevated point and volume sources is similar in form to the Air Quality Display Model (Environmental Protection Agency, 1969) and the Climatological Dispersion Model (Calder, 1971). In the model, the area surrounding a continuous source of pollutants is divided into sectors of equal angular width corresponding to the class intervals of the seasonal and annual frequency distributions of wind direction. The emission rate during a season or year is partitioned according to the relative wind-direction frequencies. Ground-level concentration fields for each source are translated to a common reference coordinate grid system and summed to obtain the total due to all emissions. For a single source the mean seasonal concentration at a point (r, θ) is given by

$$\chi_{\ell}\{r,\theta\} = \frac{2KQ}{\sqrt{2\pi}\; r\,\Delta\theta'} \sum_{i,j,k} \left[\frac{f_{i,j,k,\ell}}{\bar{u}_i\{H_{i,k,\ell}\}\,\sigma_{z;i,k,\ell}}\, S\{\theta\}\, V_{i,k,\ell}\, \exp\left[-\psi\, r/\bar{u}_i\{H_{i,k,\ell}\}\right]\right] \tag{23}$$

$$V_{i,k,\ell} = \exp\left[-\frac{1}{2}\left(\frac{H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2\right] + \sum_{n=1}^{\infty}\left\{\exp\left[-\frac{1}{2}\left(\frac{2n\,H_{m;i,k,\ell} - H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2n\,H_{m;i,k,\ell} + H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2\right]\right\} \tag{24}$$

where

$f_{i,j,k,\ell}$ = frequency of occurrence of the i^{th} wind-speed category, j^{th} wind-direction category and k^{th} stability or time-of-day category for the ℓ^{th} season

$\Delta\theta'$ = the sector width in radians

$S\{\theta\}$ = a smoothing function

$$= \left\{ \begin{array}{ll} \dfrac{\Delta\theta' - \left|\theta'_j - \theta'\right|}{\Delta\theta'} & ; \left|\theta'_j - \theta'\right| \leq \Delta\theta' \\ 0 & ; \left|\theta'_j - \theta'\right| > \Delta\theta' \end{array} \right\} \tag{25}$$

θ'_j = the angle measured in radians from north to the centerline of the j^{th} wind-direction sector

θ' = the angle measured in radians from north to the point (r, θ)

As with the short-term model, the Vertical Term given by Equation (24) is changed to the form

$$V_{i,k,\ell} = \frac{\sqrt{2\pi}\ \sigma_{z;i,k,\ell}}{2H_{m;i,k,\ell}} \tag{26}$$

when the exponential terms in Equation (24) become non-zero for n equal 3. The remaining terms in Equations (23) and (24) are identical to those previously defined in Section A. 3. 1 for the short-term model except that the turbulent intensities and potential temperature gradients may be separately assigned to each wind-speed and/or stability (or time-of-day) category; the ambient air temperatures may be separately assigned to each stability (or time-of-day) category for each season; and the surface mixing depths may be separately assigned to each wind-speed and/or stability (or time-of-day) category for each season.

As shown by Equation (25), the rectangular concentration distribution within a given angular sector is modified by the function $S\{\theta\}$ which smoothes discontinuities in the concentration at the boundaries of adjacent sectors. The centerline concentration in each sector is unaffected by contributions from adjacent sectors. At points off the sector centerline, the concentration is a weighted function of the concentration at the centerline of the sector in which the calculation is being made and the concentration at the centerline of the nearest adjoining sector.

The mean annual concentration at the point (r,θ) is calculated from the seasonal concentrations using the expression

$$\chi_a\{r,\theta\} = \frac{1}{4}\sum_{\ell}\chi_{\ell}\{r,\theta\} \qquad (27)$$

A.4.2 Application of the Long-Term Model to Low-Level Emissions

Long-term ground-level concentrations produced by low-level emissions are calculated from Equation (23) by setting the source height h and the buoyancy parameter F equal to zero. The standard deviation of the vertical concentration distribution at the downwind edge of the building σ_{zo} is defined as the building height divided by 2.15. Separate vertical turbulent intensities σ_E' may be defined for the low-level sources to account for the effects of surface heat sources and roughness elements. A virtual point source is used to account for the initial lateral dimension of the source in a manner identical to that described below for area sources.

A.4.3 Long-Term Concentration Model for Area Sources

The mean seasonal concentration at downwind distance r with respect to the center of an area source is given by the expression

$$\chi_{\ell}\{r > r_o\} = \frac{2KQ}{\sqrt{2\pi}\, R\, \Delta\theta'} \left\{ \sum_{i,j,k} \left[\frac{f_{i,j,k,\ell}}{\bar{u}_i\{h\}\ \sigma_{z;i,k}}\ S\{\theta\}\ V_{i,k,\ell} \right] \right\} \tag{28}$$

$$\exp\left[-\psi(r' - r_o)/\bar{u}_i\{h\}\right]$$

where

R = radial distance from the virtual point source to the receptor

$= \left((r' + x_y)^2 + y^2\right)^{1/2}$

r' = distance from source center to receptor, measured along the plume axis

r_o = effective source radius

y = lateral distance from the cloud axis to the receptor

x_y = virtual distance

$$= r_o \cot \frac{\Delta\theta'}{2} \tag{29}$$

$$\sigma_{z;i,k} = \left\{ \begin{array}{ll} \dfrac{2\sigma'_{E;i,k}\ r_o}{\ell n\left[\dfrac{\sigma'_{E;i,k}(r' + r_o) + h}{\sigma'_{E;i,k}(r' - r_o) + h}\right]} & ; \quad r_o < r' < 6r_o \\ \sigma'_{E;i,k}\ r' + h & ; \quad r' \ge 6r_o \end{array} \right\} \tag{30}$$

$$V_{i,k,\ell} = \left\{ \begin{array}{ll} 1 + 2 \sum_{n\;1}^{3} \exp\left[-\frac{1}{2} \left(\frac{2n\, H_{m;i,k,\ell}}{\sigma_{z;i,k}} \right)^2 \right] & ; \exp\left[-\frac{1}{2} \left(\frac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}} \right)^2 \right] = 0 \\ \frac{\sqrt{2\pi}\, \sigma_{z;i,k,}}{2H_{m;i,k\;\ell}} & ; \exp\left[-\frac{1}{2} \left(\frac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}} \right)^2 \right] > 0 \end{array} \right\} \quad (31)$$

and the remaining parameters are identical to those previously defined.

For points interior to the area source, the concentration for seasonal models is given by the expression

$$\chi_\ell\{r \leq r_o\} = \frac{2K\,Q}{\sqrt{2\pi}\, x_o\, y_o} \sum_{i,j,k} \left[\frac{f_{i,j,k,\ell}}{\bar{u}_i\{h\}\, \sigma'_{E;i,k}} \ln \left[\frac{\sigma'_{E;i,k}\,(r''+1) + h}{\sigma'_{E;i,k,} + h} \right] V_{i,k,\ell} \right] \quad (32)$$

where

r'' = the downwind distance, measured along the plume axis from the upwind edge of the area source

A. 5 APPLICATION OF THE SHORT-TERM AND LONG-TERM CONCENTRATION MODELS IN COMPLEX TERRAIN

The short-term and long-term concentration models described in Sections A. 3 and A. 4 are strictly applicable only for flat terrain where the base of the stack (or the building source) and the ground surface downwind from the source are at the same elevation. However, both models may also be applied to complex terrain by defining effective stabilization heights and mixing depths. The following assumptions are made in the model calculations for complex terrain:

- The top of the surface mixing layer extends over the calculation grid at a constant height above mean sea level
- Ground-level concentrations at all grid points above the top of the surface mixing layer are zero
- Plumes that stabilize above the top of the surface mixing layer do not contribute to ground-level concentrations at any grid point (this assumption also applies to flat terrain)

In order to determine whether the stabilized plume is contained within the surface mixing layer, it is necessary to calculate the mixing depth $H_m^*\{z_s\}$ at the source from the relationship

$$H_m^*\{z_s\} = (H_m + z_a - z_s) \tag{33}$$

where

H_m = the depth of the surface mixing layer measured at a point with elevation z_a above mean sea level

z_s = the height above mean sea level of the source

Equation (33) is represented schematically in Figure A-1. As shown by the figure, the actual top of the surface mixing layer is assumed to remain at a constant elevation above mean sea level. If the height H of the stabilized plume above the base of the stack is less than or equal to $Hm^*\{z_s\}$, the plume is defined to be contained within the surface mixing layer.

The height H_o of the stabilized plume above mean sea level is given by the sum of the height H of the stabilized plume above the base of the stack and the elevation z_s of the base of the stack. At any elevation z above mean sea level, the effective height $H'\{z\}$ of the plume centerline above the terrain is then given by

$$H'\{z\} = \begin{Bmatrix} H_o - z; & H_o - z \geq 0 \\ 0; & H_o - z < 0 \end{Bmatrix} \tag{34}$$

For building sources, $H'\{z\}$ is always set equal to zero.

The effective mixing depth $H_m'\{z\}$ above a point at elevation z above mean sea level is defined by

$$H_m'\{z\} = \begin{Bmatrix} H_m & ; \; z \geq z_a \\ H_m + (z_a - z) & ; \; z < z_a \end{Bmatrix} \tag{35}$$

Figure A-2 illustrates the assumptions implicit in Equation (35). For grid points at elevations below the airport elevation, the effective mixing depth $H_m'\{z\}$ is allowed to increase in a manner consistent with Figure A-1. However, in order to prevent a physically unrealistic compression of plumes as they pass over elevated terrain, the effective mixing depth is not permitted to be less than the mixing depth measured at the airport. It should be noted that the concentration is set equal to zero for grid points above the actual top of the mixing layer (see Figure A-1).

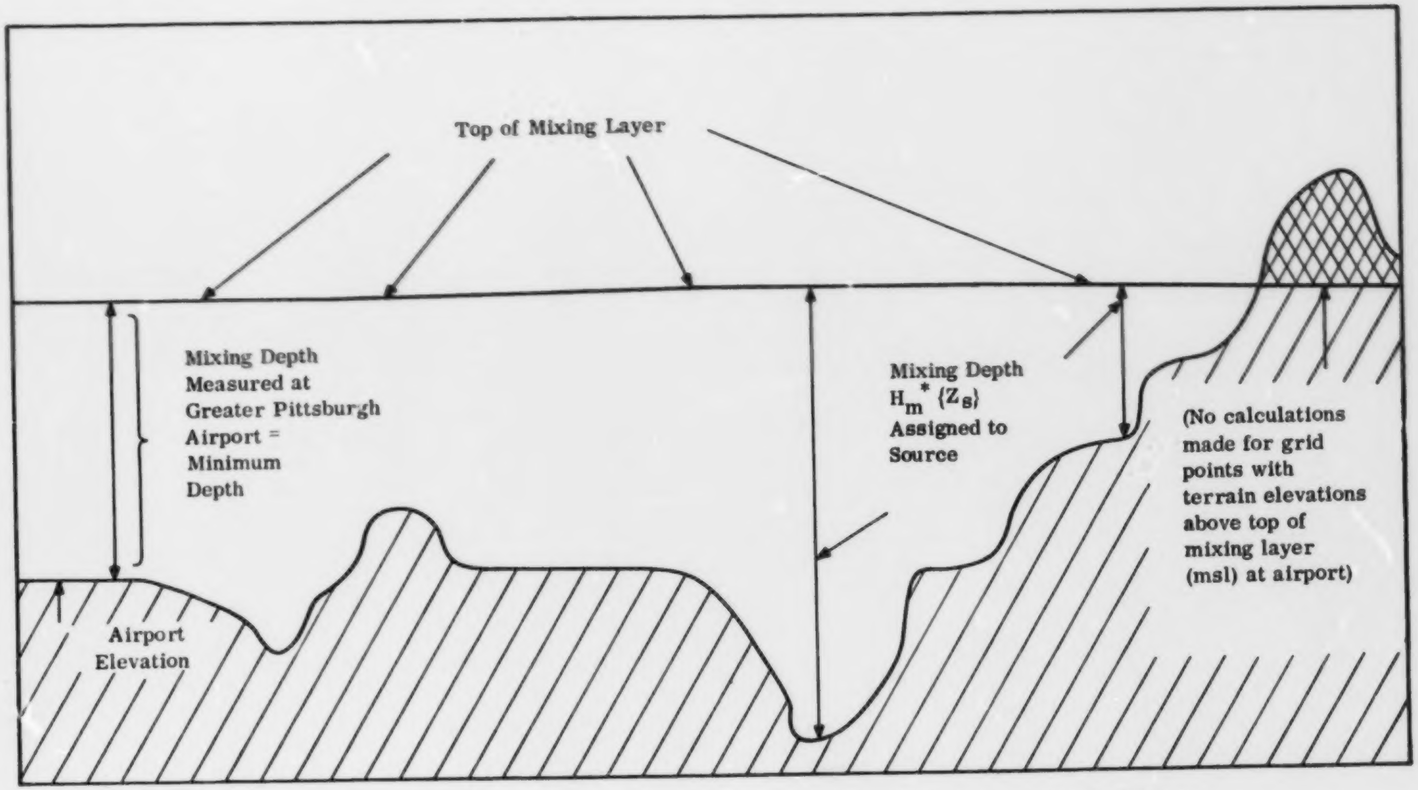
Top of Mixing Layer
Mixing Depth Measured at Greater Pittsburgh Airport = Minimum Depth
Airport Elevation
Mixing Depth $H_m^* \{Z_s\}$ Assigned to Source
(No calculations made for grid points with terrain elevations above top of mixing layer (msl) at airport)

FIGURE A-1. Mixing depth $H_m^*\{z_s\}$ used to determine whether the stabilized plume is contained within the surface mixing layer.

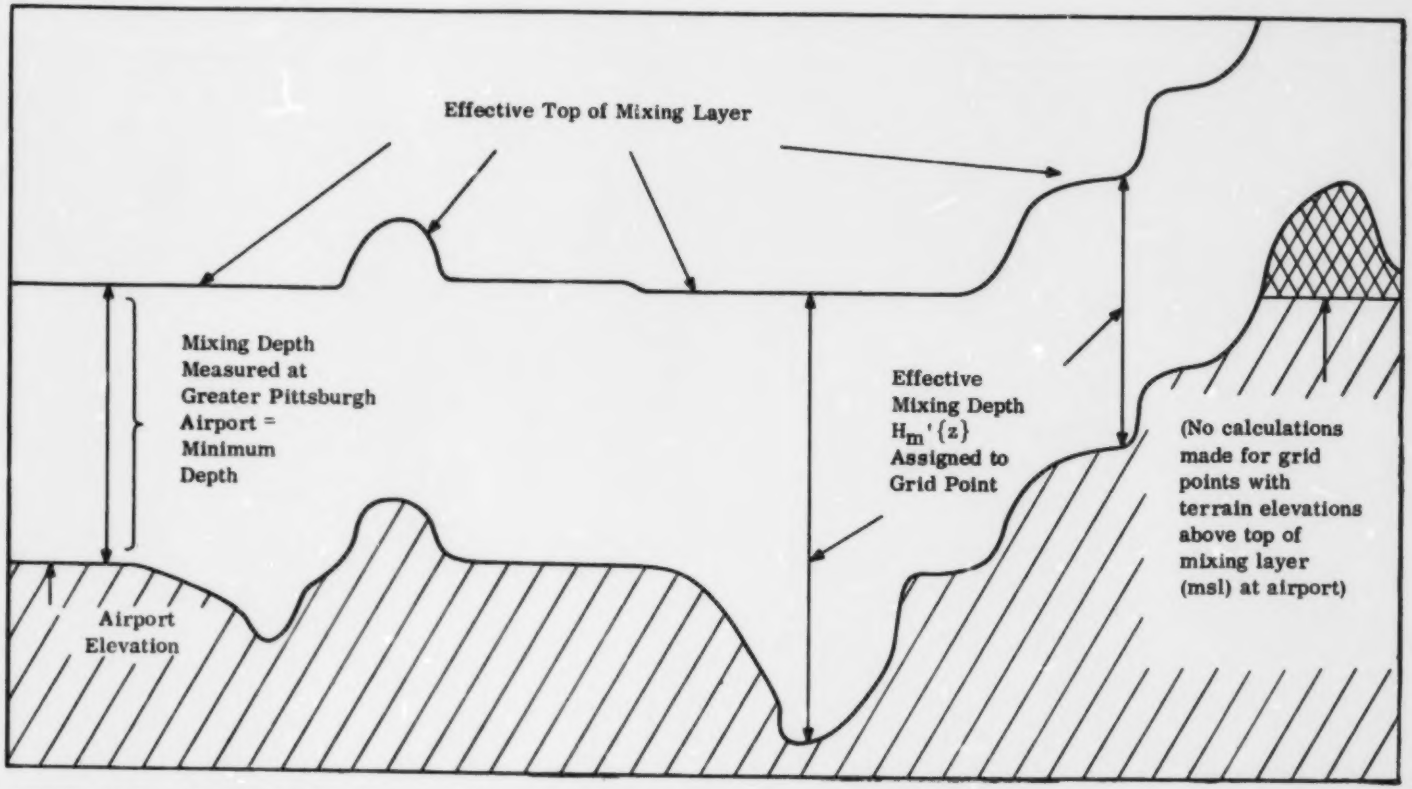
Effective Top of Mixing Layer
Mixing Depth Measured at Greater Pittsburgh Airport = Minimum Depth
Airport Elevation
Effective Mixing Depth $H_m'\{z\}$ Assigned to Grid Point
(No calculations made for grid points with terrain elevations above top of mixing layer (msl) at airport)

FIGURE A-2. Effective mixing depth $H_m'\{z\}$ assigned to grid points for the concentration calculations.

The terrain adjustment procedures also assume that the mean wind speed at any given height above sea level is constant. Thus, the wind speed $\bar{u}_R$ measured at height z_R above the surface at a point with elevation z_a above mean sea level is adjusted to the stack height for the plume rise calculations by the relationship

$$\bar{u}\{h\} = \begin{Bmatrix} \bar{u}_R \left(\dfrac{h_o - z_z}{z_R} \right)^p & ; \ h_o \geq z_a + z_R \\ \bar{u}_R & ; \ h_o < z_a + z_R \end{Bmatrix} \tag{36}$$

where h_o is height above mean sea level of the top of the stack. Similarly, the wind speed $\bar{u}\{H\}$ used in the concentration calculations is given by

$$\bar{u}\{H\} = \begin{Bmatrix} \bar{u}_R \left(\dfrac{H_o - z_a}{z_R} \right)^p & ; \ H_o \geq z_a + z_R \\ \bar{u}_R & ; \ H_o < z_a + z_R \end{Bmatrix} \tag{37}$$

It should be noted that the terrain-adjustment procedures outlined above provide a very simple representation of complex plume-terrain interactions that are not yet well understood. Because the model assumptions are generally conservative, it is possible that concentrations calculated for elevated terrain, especially elevated terrain near a source, exceed the concentrations that actually occur. It should also be noted that the procedures described above differ from previous "terrain-intersection" models in that terrain intersection is only permitted for a plume contained within a mixing layer. That is, terrain intersection is permitted for all stability categories, but only for a plume contained within the surface mixing layer.

APPENDIX B

JOINT FREQUENCY DISTRIBUTIONS OF WIND-SPEED AND WIND-DIRECTION CATEGORIES

Tables B-1, B-2, B-3 and B-4 list the seasonal joint frequency of occurrence by Pasquill stability category* of wind-speed and wind-direction categories for the winter, spring, summer and fall of 1973, respectively. The corresponding seasonal distribution for 1965 are given in Tables B-5 through B-8. These distributions were developed from surface weather observations by the STAR program of the National Climatic Center which uses the Turner (1964) definitions of the Pasquill stability categories. The 1973 distributions were derived from hourly surface wind speed and wind direction observations at Allegheny County Airport and 3-hourly cloud cover observations at the Greater Pittsburgh Airport. The 1965 distributions were developed from 3-hourly surface weather observations at the Greater Pittsburgh Airport.

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*In the tables, the Pasquill A through F stability categories are labeled 1 through 6. The E and F stability categories were combined in the seasonal and annual concentration calculations.

TABLE B-1

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR WINTER 1973

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00003470	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-1 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00016670	.00055560	.00000000	.00000000	.00000000	.00000000
67.500	.00050000	.00166670	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00016670	.00055560	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00105560	.00111110	.00000000	.00000000	.00000000	.00000000
225.000	.00016670	.00055560	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00016670	.00055560	.00055560	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-1 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00002780	.00111110	.00222220	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00055560	.00000000	.00000000	.00000000
45.000	.00005560	.00222220	.00111110	.00000000	.00000000	.00000000
67.500	.00006940	.00277780	.00055560	.00000000	.00000000	.00000000
90.000	.00123610	.00388890	.00277780	.00000000	.00000000	.00000000
112.500	.00002780	.00111110	.00000000	.00000000	.00000000	.00000000
135.000	.00001390	.00055560	.00055560	.00000000	.00000000	.00000000
157.500	.00002780	.00111110	.00000000	.00000000	.00000000	.00000000
180.000	.00004170	.00166670	.00277780	.00000000	.00000000	.00000000
202.500	.00008330	.00333330	.00333330	.00000000	.00000000	.00000000
225.000	.00002780	.00111110	.00166670	.00000000	.00000000	.00000000
247.500	.00001390	.00055560	.00333330	.00000000	.00000000	.00000000
270.000	.00001390	.00055560	.00111110	.00000000	.00000000	.00000000
292.500	.00002780	.00111110	.00055560	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00111110	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-1 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00038100	.00999999	.02333329	.00555560	.00000000	.00000000
22.500	.00078840	.00555560	.00777780	.00000000	.00000000	.00000000
45.000	.00065190	.00722220	.00444440	.00055560	.00000000	.00000000
67.500	.00089420	.00833330	.01111109	.00166670	.00000000	.00000000
90.000	.00151320	.00944440	.01722219	.00222220	.00000000	.00000000
112.500	.00021160	.00555560	.02611109	.01111109	.00000000	.00000000
135.000	.00023280	.00611110	.02833329	.01611109	.00000000	.00000000
157.500	.00016930	.00444440	.01444439	.00277780	.00000000	.00000000
180.000	.00048680	.01277779	.03944438	.00444440	.00000000	.00000000
202.500	.00029630	.00777780	.02777779	.00888890	.00111110	.00000000
225.000	.00040210	.01055559	.02555559	.03333328	.00000000	.00000000
247.500	.00093650	.00944440	.05611107	.08722216	.00166670	.00000000
270.000	.00256080	.00666670	.02666669	.03833328	.00000000	.00000000
292.500	.00006350	.00166670	.02055559	.01666669	.00000000	.00000000
315.000	.00002120	.00055560	.01555559	.00722220	.00055560	.00000000
337.500	.00019050	.00500000	.01777779	.01611109	.00055560	.00000000

TABLE B-1 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00388890	.00388890	.00000000	.00000000	.00000000
22.500	.00000000	.00222220	.00055560	.00000000	.00000000	.00000000
45.000	.00000000	.00722220	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00500000	.00055560	.00000000	.00000000	.00000000
90.000	.00000000	.00500000	.00055560	.00000000	.00000000	.00000000
112.500	.00000000	.00166670	.00222220	.00000000	.00000000	.00000000
135.000	.00000000	.00388890	.00111110	.00000000	.00000000	.00000000
157.500	.00000000	.00277780	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00777780	.02111109	.00000000	.00000000	.00000000
202.500	.00000000	.00166670	.01388889	.00000000	.00000000	.00000000
225.000	.00000000	.00055560	.01055559	.00000000	.00000000	.00000000
247.500	.00000000	.00055560	.01055559	.00000000	.00000000	.00000000
270.000	.00000000	.00388890	.00777780	.00000000	.00000000	.00000000
292.500	.00000000	.00111110	.00166670	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00166670	.00000000	.00000000	.00000000
337.500	.00000000	.00222220	.00222220	.00000000	.00000000	.00000000

TABLE B-1 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00116160	.00611110	.00000000	.00000000	.00000000	.00000000
22.500	.00101010	.00444440	.00000000	.00000000	.00000000	.00000000
45.000	.00070710	.00777780	.00000000	.00000000	.00000000	.00000000
67.500	.00151520	.00999999	.00000000	.00000000	.00000000	.00000000
90.000	.00035350	.00388890	.00000000	.00000000	.00000000	.00000000
112.500	.00121210	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00015150	.00166670	.00000000	.00000000	.00000000	.00000000
157.500	.00020200	.00222220	.00000000	.00000000	.00000000	.00000000
180.000	.00141410	.00888890	.00000000	.00000000	.00000000	.00000000
202.500	.00045450	.00500000	.00000000	.00000000	.00000000	.00000000
225.000	.00040400	.00444440	.00000000	.00000000	.00000000	.00000000
247.500	.00015150	.00166670	.00000000	.00000000	.00000000	.00000000
270.000	.00186870	.00722220	.00000000	.00000000	.00000000	.00000000
292.500	.00035350	.00388890	.00000000	.00000000	.00000000	.00000000
315.000	.00010100	.00111110	.00000000	.00000000	.00000000	.00000000
337.500	.00060610	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-2

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR SPRING 1973

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00054350	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-2 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00010520	.00326090	.00000000	.00000000	.00000000	.00000000
22.500	.00003510	.00108700	.00000000	.00000000	.00000000	.00000000
45.000	.00003510	.00108700	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00059610	.00108700	.00054350	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00054350	.00000000	.00000000	.00000000
157.500	.00001750	.00054350	.00054350	.00000000	.00000000	.00000000
180.000	.00003510	.00108700	.00326090	.00000000	.00000000	.00000000
202.500	.00001750	.00054350	.00108700	.00000000	.00000000	.00000000
225.000	.00003510	.00108700	.00000000	.00000000	.00000000	.00000000
247.500	.00120970	.00271740	.00054350	.00000000	.00000000	.00000000
270.000	.00005260	.00163040	.00054350	.00000000	.00000000	.00000000
292.500	.00001750	.00054350	.00000000	.00000000	.00000000	.00000000
315.000	.00001750	.00054350	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00054350	.00000000	.00000000	.00000000

TABLE B-2 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00005300	.00217390	.00380430	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00217390	.00000000	.00000000	.00000000
45.000	.00055670	.00000000	.00108700	.00000000	.00000000	.00000000
67.500	.00005300	.00217390	.00163040	.00000000	.00000000	.00000000
90.000	.00002650	.00108700	.00217390	.00000000	.00000000	.00000000
112.500	.00001330	.00054350	.00217390	.00054350	.00000000	.00000000
135.000	.00000000	.00000000	.00217390	.00000000	.00000000	.00000000
157.500	.00005300	.00217390	.00489130	.00000000	.00000000	.00000000
180.000	.00006630	.00271740	.00652169	.00054350	.00000000	.00000000
202.500	.00001330	.00054350	.00597629	.00054350	.00000000	.00000000
225.000	.00007950	.00326090	.00326090	.00054350	.00000000	.00000000
247.500	.00005300	.00217390	.00271740	.00163040	.00000000	.00000000
270.000	.00060980	.00217390	.00326090	.00163040	.00000000	.00000000
292.500	.00001330	.00054350	.00163040	.00108700	.00000000	.00000000
315.000	.00001330	.00054350	.00054350	.00108700	.00000000	.00000000
337.500	.00002650	.00108700	.00271740	.00108700	.00000000	.00000000

TABLE B-2 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATFGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00068410	.00543479	.01647828	.00760869	.00000000	.00000000
22.500	.00012790	.00543479	.00923909	.00163040	.00000000	.00000000
45.000	.00024300	.01032609	.00923909	.00108700	.00000000	.00000000
67.500	.00028130	.01195649	.01358699	.00000000	.00000000	.00000000
90.000	.00093990	.01630428	.02391298	.00217390	.00000000	.00000000
112.500	.00025580	.01086959	.03260867	.01304349	.00000000	.00000000
135.000	.00017900	.00760869	.03206517	.01956518	.00054350	.00000000
157.500	.00014070	.00597829	.02771737	.01086959	.00000000	.00000000
180.000	.00093990	.01630428	.03423907	.00543479	.00000000	.00000000
202.500	.00016620	.00706519	.01956518	.00543479	.00054350	.00000000
225.000	.00078640	.00978259	.03315217	.02391298	.00326090	.00000000
247.500	.00077370	.00923909	.04076086	.04076086	.00597829	.00108700
270.000	.00024300	.01032609	.02717387	.04836956	.00434780	.00000000
292.500	.00005120	.00217390	.00923909	.01358699	.00108700	.00000000
315.000	.00063300	.00326090	.00815219	.00271740	.00000000	.00000000
337.500	.00007670	.00326090	.00706519	.00489130	.00000000	.00000000

TABLE B-2 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00108700	.00597829	.00000000	.00000000	.00000000
22.500	.00000000	.00326090	.00271740	.00000000	.00000000	.00000000
45.000	.00000000	.00543479	.00054350	.00000000	.00000000	.00000000
67.500	.00000000	.00706519	.00054350	.00000000	.00000000	.00000000
90.000	.00000000	.00543479	.00163040	.00000000	.00000000	.00000000
112.500	.00000000	.00923909	.00543479	.00000000	.00000000	.00000000
135.000	.00000000	.00326090	.00380430	.00000000	.00000000	.00000000
157.500	.00000000	.00597829	.00217390	.00000000	.00000000	.00000000
180.000	.00000000	.01195649	.00271740	.00000000	.00000000	.00000000
202.500	.00000000	.00760869	.00434780	.00000000	.00000000	.00000000
225.000	.00000000	.00597829	.00434780	.00000000	.00000000	.00000000
247.500	.00000000	.00652169	.00163040	.00000000	.00000000	.00000000
270.000	.00000000	.00543479	.00271740	.00000000	.00000000	.00000000
292.500	.00000000	.00108700	.00108700	.00000000	.00000000	.00000000
315.000	.00000000	.00163040	.00326090	.00000000	.00000000	.00000000
337.500	.00000000	.00108700	.00217390	.00000000	.00000000	.00000000

TABLE B-2 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00045710	.00543479	.00000000	.00000000	.00000000	.00000000
22.500	.00090920	.00380430	.00000000	.00000000	.00000000	.00000000
45.000	.00131550	.00163040	.00000000	.00000000	.00000000	.00000000
67.500	.00086350	.00326090	.00000000	.00000000	.00000000	.00000000
90.000	.00018290	.00217390	.00000000	.00000000	.00000000	.00000000
112.500	.00027430	.00326090	.00000000	.00000000	.00000000	.00000000
135.000	.00090920	.00380430	.00000000	.00000000	.00000000	.00000000
157.500	.00036570	.00434760	.00000000	.00000000	.00000000	.00000000
180.000	.00032000	.00380430	.00000000	.00000000	.00000000	.00000000
202.500	.00018290	.00217390	.00000000	.00000000	.00000000	.00000000
225.000	.00032000	.00380430	.00000000	.00000000	.00000000	.00000000
247.500	.00054860	.00652169	.00000000	.00000000	.00000000	.00000000
270.000	.00090920	.00380430	.00000000	.00000000	.00000000	.00000000
292.500	.00027430	.00326090	.00000000	.00000000	.00000000	.00000000
315.000	.00013710	.00163040	.00000000	.00000000	.00000000	.00000000
337.500	.00018290	.00217390	.00000000	.00000000	.00000000	.00000000

TABLE B-3

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR SUMMER 1973

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00038820	.00163040	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00012940	.00054350	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00012940	.00054350	.00000000	.00000000	.00000000	.00000000
135.000	.00012940	.00054350	.00000000	.00000000	.00000000	.00000000
157.500	.00012940	.00054350	.00000000	.00000000	.00000000	.00000000
180.000	.00064700	.00271740	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00012940	.00054350	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00064700	.00271740	.00000000	.00000000	.00000000	.00000000
292.500	.00012940	.00054350	.00000000	.00000000	.00000000	.00000000
315.000	.00025880	.00108700	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-3 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00002810	.00108700	.00054350	.00000000	.00000000	.00000000
22.500	.00004220	.00163040	.00000000	.00000000	.00000000	.00000000
45.000	.00055750	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00002810	.00108700	.00000000	.00000000	.00000000	.00000000
90.000	.00118530	.00271740	.00000000	.00000000	.00000000	.00000000
112.500	.00005620	.00217390	.00054350	.00000000	.00000000	.00000000
135.000	.00064190	.00326090	.00054350	.00000000	.00000000	.00000000
157.500	.00061380	.00217390	.00108700	.00000000	.00000000	.00000000
180.000	.00078240	.00669570	.00271740	.00000000	.00000000	.00000000
202.500	.00026710	.01032610	.00271740	.00000000	.00000000	.00000000
225.000	.00015460	.00597830	.00271740	.00000000	.00000000	.00000000
247.500	.00074030	.00706520	.00489130	.00000000	.00000000	.00000000
270.000	.00015460	.00597830	.00217390	.00000000	.00000000	.00000000
292.500	.00005620	.00217390	.00054350	.00000000	.00000000	.00000000
315.000	.00005620	.00217390	.00000000	.00000000	.00000000	.00000000
337.500	.00007030	.00271740	.00000000	.00000000	.00000000	.00000000

TABLE B-3 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00025080	.00326090	.00760870	.00000000	.00000000	.00000000
22.500	.00012540	.00163040	.00054350	.00000000	.00000000	.00000000
45.000	.00004180	.00054350	.00000000	.00000000	.00000000	.00000000
67.500	.00016720	.00217390	.00000000	.00000000	.00000000	.00000000
90.000	.00012540	.00163040	.00054350	.00000000	.00000000	.00000000
112.500	.00016720	.00217390	.00108700	.00000000	.00000000	.00000000
135.000	.00012540	.00163040	.00271740	.00000000	.00000000	.00000000
157.500	.00037630	.00489130	.00326090	.00000000	.00000000	.00000000
180.000	.00175590	.01521739	.01630429	.00108700	.00000000	.00000000
202.500	.00062710	.00815220	.01086959	.00163040	.00000000	.00000000
225.000	.00041810	.00543480	.01684779	.00163040	.00000000	.00000000
247.500	.00050170	.00652170	.01413039	.00380430	.00000000	.00000000
270.000	.00104520	.00597830	.00543480	.00054350	.00000000	.00000000
292.500	.00004180	.00054350	.00217390	.00000000	.00000000	.00000000
315.000	.00004180	.00054350	.00326090	.00054350	.00000000	.00000000
337.500	.00016720	.00217390	.00108700	.00000000	.00000000	.00000000

TABLE B-3 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00016720	.00869570	.01304349	.00271740	.00000000	.00000000
22.500	.00005230	.00271740	.00108700	.00000000	.00000000	.00000000
45.000	.00008360	.00434780	.00108700	.00000000	.00000000	.00000000
67.500	.00128550	.00923910	.00163040	.00000000	.00000000	.00000000
90.000	.00127510	.00869570	.00434780	.00054350	.00000000	.00000000
112.500	.00011500	.00597830	.00326090	.00108700	.00000000	.00000000
135.000	.00006270	.00326090	.00706520	.00000000	.00000000	.00000000
157.500	.00012540	.00652170	.01032610	.00000000	.00000000	.00000000
180.000	.00113920	.03043479	.03532608	.00054350	.00000000	.00000000
202.500	.00022990	.01195649	.02010869	.00760870	.00000000	.00000000
225.000	.00033440	.01739129	.03858698	.01630429	.00000000	.00000000
247.500	.00012540	.00652170	.02282609	.00869570	.00054350	.00000000
270.000	.00022990	.01195649	.01684779	.00217390	.00000000	.00000000
292.500	.00008360	.00434780	.00380430	.00054350	.00000000	.00000000
315.000	.00002090	.00108700	.00434780	.00054350	.00000000	.00000000
337.500	.00010450	.00543480	.00489130	.00326090	.00000000	.00000000

TABLE B-3 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00978260	.00489130	.00000000	.00000000	.00000000
22.500	.00000000	.00326090	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00271740	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00108700	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00163040	.00054350	.00000000	.00000000	.00000000
112.500	.00000000	.00434780	.00108700	.00000000	.00000000	.00000000
135.000	.00000000	.00489130	.00163040	.00000000	.00000000	.00000000
157.500	.00000000	.00652170	.00163040	.00000000	.00000000	.00000000
180.000	.00000000	.02608699	.00543480	.00000000	.00000000	.00000000
202.500	.00000000	.00978260	.01086959	.00000000	.00000000	.00000000
225.000	.00000000	.01032610	.01684779	.00000000	.00000000	.00000000
247.500	.00000000	.00869570	.00706520	.00000000	.00000000	.00000000
270.000	.00000000	.00597830	.00163040	.00000000	.00000000	.00000000
292.500	.00000000	.00108700	.00054350	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00217390	.00000000	.00000000	.00000000
337.500	.00000000	.00163040	.00271740	.00000000	.00000000	.00000000

TABLE B-3 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00532670	.01467369	.00000000	.00000000	.00000000	.00000000
22.500	.00022390	.00271740	.00000000	.00000000	.00000000	.00000000
45.000	.00144520	.00326090	.00000000	.00000000	.00000000	.00000000
67.500	.00171380	.00652170	.00000000	.00000000	.00000000	.00000000
90.000	.00166900	.00597830	.00000000	.00000000	.00000000	.00000000
112.500	.00035820	.00434780	.00000000	.00000000	.00000000	.00000000
135.000	.00166900	.00597830	.00000000	.00000000	.00000000	.00000000
157.500	.00153470	.00434780	.00000000	.00000000	.00000000	.00000000
180.000	.00440030	.03913058	.00000000	.00000000	.00000000	.00000000
202.500	.00246880	.02282609	.00000000	.00000000	.00000000	.00000000
225.000	.00206580	.01793479	.00000000	.00000000	.00000000	.00000000
247.500	.00319140	.02445649	.00000000	.00000000	.00000000	.00000000
270.000	.00247500	.01576089	.00000000	.00000000	.00000000	.00000000
292.500	.00022390	.00271740	.00000000	.00000000	.00000000	.00000000
315.000	.00085690	.00326090	.00000000	.00000000	.00000000	.00000000
337.500	.00026870	.00326090	.00000000	.00000000	.00000000	.00000000

TABLE B-4

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR FALL 1973

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00006870	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-4 (Continued)

```
                               STABILITY CATEGORY 2

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION     (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
        .000      .00073680   .00219779   .00054950   .00000000   .00000000   .00000000
      22.500      .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
      45.000      .00018750   .00274729   .00054950   .00000000   .00000000   .00000000
      67.500      .00003750   .00054950   .00000000   .00000000   .00000000   .00000000
      90.000      .00014990   .00219779   .00164839   .00000000   .00000000   .00000000
     112.500      .00007490   .00109890   .00109890   .00000000   .00000000   .00000000
     135.000      .00073680   .00219779   .00000000   .00000000   .00000000   .00000000
     157.500      .00062440   .00054950   .00000000   .00000000   .00000000   .00000000
     180.000      .00022480   .00329669   .00219779   .00000000   .00000000   .00000000
     202.500      .00011240   .00164839   .00054950   .00000000   .00000000   .00000000
     225.000      .00003750   .00054950   .00054950   .00000000   .00000000   .00000000
     247.500      .00003750   .00054950   .00000000   .00000000   .00000000   .00000000
     270.000      .00007490   .00109890   .00054950   .00000000   .00000000   .00000000
     292.500      .00003750   .00054950   .00054950   .00000000   .00000000   .00000000
     315.000      .00014990   .00219779   .00109890   .00000000   .00000000   .00000000
     337.500      .00007490   .00109890   .00000000   .00000000   .00000000   .00000000
```

TABLE B-4 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00003820	.00274729	.00274729	.00000000	.00000000	.00000000
22.500	.00003050	.00219779	.00000000	.00000000	.00000000	.00000000
45.000	.00002290	.00164839	.00164839	.00000000	.00000000	.00000000
67.500	.00004580	.00329669	.00219779	.00000000	.00000000	.00000000
90.000	.00008390	.00604398	.00494508	.00000000	.00000000	.00000000
112.500	.00059520	.00274729	.00384619	.00000000	.00000000	.00000000
135.000	.00000760	.00054950	.00604398	.00000000	.00000000	.00000000
157.500	.00003050	.00219779	.00219779	.00000000	.00000000	.00000000
180.000	.00004870	.00659338	.01043957	.00000000	.00000000	.00000000
202.500	.00002290	.00164839	.00329669	.00000000	.00000000	.00000000
225.000	.00002290	.00164839	.00604398	.00054950	.00000000	.00000000
247.500	.00003820	.00274729	.00494508	.00000000	.00000000	.00000000
270.000	.00003050	.00219779	.00604398	.00000000	.00000000	.00000000
292.500	.00001530	.00109890	.00274729	.00054950	.00000000	.00000000
315.000	.00000000	.00000000	.00439559	.00000000	.00000000	.00000000
337.500	.00001530	.00109890	.00329669	.00000000	.00000000	.00000000

TABLE B-4 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00114420	.00714288	.00549448	.00000000	.00000000	.00000000
22.500	.00042480	.00549448	.00329669	.00054950	.00000000	.00000000
45.000	.00068930	.00384619	.00164839	.00000000	.00000000	.00000000
67.500	.00029740	.00384619	.00329669	.00000000	.00000000	.00000000
90.000	.00110170	.00659338	.00934067	.00000000	.00000000	.00000000
112.500	.00033990	.00439559	.01648344	.00164839	.00000000	.00000000
135.000	.00033990	.00439559	.01978013	.00384619	.00000000	.00000000
157.500	.00093180	.00439559	.01428565	.00054950	.00000000	.00000000
180.000	.00173899	.01483515	.03571418	.00659338	.00000000	.00000000
202.500	.00050980	.00659338	.03131860	.01043957	.00000000	.00000000
225.000	.00135660	.00989007	.03956027	.02307682	.00000000	.00000000
247.500	.00093460	.01208786	.03241749	.02362632	.00274729	.00164839
270.000	.00055230	.00714288	.02747241	.03901087	.00219779	.00000000
292.500	.00029740	.00384619	.00934067	.01428565	.00000000	.00000000
315.000	.00004250	.00054950	.00659338	.00989007	.00000000	.00000000
337.500	.00083720	.00824177	.01208786	.00274729	.00000000	.00000000

TABLE B-4 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00769227	.00164839	.00000000	.00000000	.00000000
22.500	.00000000	.00494508	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00329669	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00659336	.00054950	.00000000	.00000000	.00000000
90.000	.00000000	.00824177	.00219779	.00000000	.00000000	.00000000
112.500	.00000000	.00274729	.00329669	.00000000	.00000000	.00000000
135.000	.00000000	.00439559	.00714288	.00000000	.00000000	.00000000
157.500	.00000000	.00549448	.00824177	.00000000	.00000000	.00000000
180.000	.00000000	.00934067	.01648344	.00000000	.00000000	.00000000
202.500	.00000000	.00549448	.00604398	.00000000	.00000000	.00000000
225.000	.00000000	.00769227	.00329669	.00000000	.00000000	.00000000
247.500	.00000000	.00384619	.01098896	.00000000	.00000000	.00000000
270.000	.00000000	.00549448	.00679117	.00000000	.00000000	.00000000
292.500	.00000000	.00164839	.00274729	.00000000	.00000000	.00000000
315.000	.00000000	.00109890	.00109690	.00000000	.00000000	.00000000
337.500	.00000000	.00109890	.00109690	.00000000	.00000000	.00000000

TABLE B-4 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00324049	.01153846	.00000000	.00000000	.00000000	.00000000
22.500	.00109160	.00659358	.00000000	.00000000	.00000000	.00000000
45.000	.00278169	.00549448	.00000000	.00000000	.00000000	.00000000
67.500	.00362439	.01923074	.00000000	.00000000	.00000000	.00000000
90.000	.00244079	.00879117	.00000000	.00000000	.00000000	.00000000
112.500	.00143260	.00329669	.00000000	.00000000	.00000000	.00000000
135.000	.00117510	.00769227	.00000000	.00000000	.00000000	.00000000
157.500	.00155039	.01263736	.00000000	.00000000	.00000000	.00000000
180.000	.00255869	.01813184	.00000000	.00000000	.00000000	.00000000
202.500	.00197479	.01043957	.00000000	.00000000	.00000000	.00000000
225.000	.00248249	.00934067	.00000000	.00000000	.00000000	.00000000
247.500	.00155039	.01263736	.00000000	.00000000	.00000000	.00000000
270.000	.00169129	.00934067	.00000000	.00000000	.00000000	.00000000
292.500	.00033370	.00439559	.00000000	.00000000	.00000000	.00000000
315.000	.00020850	.00274729	.00000000	.00000000	.00000000	.00000000
337.500	.00223229	.00604398	.00000000	.00000000	.00000000	.00000000

TABLE B-5

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR WINTER 1965

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-5 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-5 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00139280	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00139280	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00139280	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00139280	.00000000	.00000000	.00000000
112.500	.00139280	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00139280	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00139280	.00139280	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00139280	.00000000	.00000000	.00000000
225.000	.00000000	.00278550	.00139280	.00000000	.00000000	.00000000
247.500	.00000000	.00557100	.00278550	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00139280	.00000000	.00000000
292.500	.00000000	.00139280	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00139280	.00139280	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-5 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00012860	.00417830	.00974929	.00974929	.00000000	.00000000
22.500	.00004290	.00139280	.00557100	.00278550	.00000000	.00000000
45.000	.00147850	.00139280	.00417830	.00417830	.00000000	.00000000
67.500	.00008570	.00278550	.00974929	.00417830	.00000000	.00000000
90.000	.00025710	.00835649	.01253479	.00139280	.00000000	.00000000
112.500	.00017140	.00557100	.01532029	.00557100	.00000000	.00000000
135.000	.00152130	.00278550	.01949859	.00417830	.00000000	.00000000
157.500	.00008570	.00278550	.01810579	.00139280	.00000000	.00000000
180.000	.00190700	.01532029	.02785518	.00974929	.00000000	.00000000
202.500	.00008570	.00278550	.02089138	.01949859	.00139280	.00000000
225.000	.00047140	.01532029	.03064068	.06267405	.00835649	.00139280
247.500	.00012860	.00417830	.03621167	.07103055	.01253479	.00000000
270.000	.00025710	.00835649	.02924788	.05710306	.02228408	.00557100
292.500	.00017140	.00557100	.01392759	.02785518	.01532029	.00139280
315.000	.00012860	.00417830	.00835649	.00696379	.00557100	.00139280
337.500	.00004290	.00139280	.00557100	.01392759	.00417830	.00000000

TABLE B-5 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00417830	.00278550	.00000000	.00000000	.00000000
22.500	.00000000	.00139280	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00278550	.00139280	.00000000	.00000000	.00000000
67.500	.00000000	.00417830	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00974929	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00278550	.00139280	.00000000	.00000000	.00000000
135.000	.00000000	.01253479	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.01532029	.00139280	.00000000	.00000000	.00000000
180.000	.00000000	.01392759	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00417830	.00139280	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.01253479	.00000000	.00000000	.00000000
247.500	.00000000	.00417830	.00417830	.00000000	.00000000	.00000000
270.000	.00000000	.00278550	.01114209	.00000000	.00000000	.00000000
292.500	.00000000	.00278550	.00557100	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00278550	.00000000	.00000000	.00000000
337.500	.00000000	.00139280	.00278550	.00000000	.00000000	.00000000

TABLE B-5 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00051930	.00278550	.00000000	.00000000	.00000000	.00000000
22.500	.00217180	.00278550	.00000000	.00000000	.00000000	.00000000
45.000	.00269110	.00557100	.00000000	.00000000	.00000000	.00000000
67.500	.00025970	.00139280	.00000000	.00000000	.00000000	.00000000
90.000	.00077900	.00417830	.00000000	.00000000	.00000000	.00000000
112.500	.00408380	.00417830	.00000000	.00000000	.00000000	.00000000
135.000	.00356450	.00139280	.00000000	.00000000	.00000000	.00000000
157.500	.00191210	.00139280	.00000000	.00000000	.00000000	.00000000
180.000	.00243140	.00417830	.00000000	.00000000	.00000000	.00000000
202.500	.00103870	.00557100	.00000000	.00000000	.00000000	.00000000
225.000	.00103870	.00557100	.00000000	.00000000	.00000000	.00000000
247.500	.00077900	.00417830	.00000000	.00000000	.00000000	.00000000
270.000	.00538220	.01114209	.00000000	.00000000	.00000000	.00000000
292.500	.00103870	.00557100	.00000000	.00000000	.00000000	.00000000
315.000	.00408380	.00417830	.00000000	.00000000	.00000000	.00000000
337.500	.00025970	.00139280	.00000000	.00000000	.00000000	.00000000

TABLE B-6

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR SPRING 1965

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00135870	.00135870	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00271740	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-6 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00015680	.00407609	.00271740	.00000000	.00000000	.00000000
22.500	.00010450	.00271740	.00000000	.00000000	.00000000	.00000000
45.000	.00146320	.00135870	.00000000	.00000000	.00000000	.00000000
67.500	.00156770	.00407609	.00271740	.00000000	.00000000	.00000000
90.000	.00167220	.00679349	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00005230	.00135870	.00135870	.00000000	.00000000	.00000000
180.000	.00005230	.00135870	.00000000	.00000000	.00000000	.00000000
202.500	.00287420	.00135870	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00135870	.00000000	.00000000	.00000000
247.500	.00005230	.00135870	.00135870	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00146320	.00135870	.00000000	.00000000	.00000000	.00000000
337.500	.00005230	.00135870	.00000000	.00000000	.00000000	.00000000

TABLE B-6 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00187630	.00135870	.00679349	.00000000	.00000000	.00000000
22.500	.00161750	.00000000	.00271740	.00000000	.00000000	.00000000
45.000	.00025880	.00135870	.00135870	.00000000	.00000000	.00000000
67.500	.00077640	.00407609	.00407609	.00000000	.00000000	.00000000
90.000	.00051760	.00271740	.00679349	.00135870	.00000000	.00000000
112.500	.00000000	.00000000	.00407609	.00000000	.00000000	.00000000
135.000	.00213510	.00271740	.00135870	.00135870	.00000000	.00000000
157.500	.00051760	.00271740	.00135870	.00000000	.00000000	.00000000
180.000	.00103520	.00543479	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00271740	.00135870	.00000000	.00000000
225.000	.00000000	.00000000	.00271740	.00000000	.00000000	.00000000
247.500	.00025880	.00135870	.00407609	.00000000	.00000000	.00000000
270.000	.00051760	.00271740	.00543479	.00407609	.00000000	.00000000
292.500	.00000000	.00000000	.00135870	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00679349	.00271740	.00000000	.00000000
337.500	.00000000	.00000000	.00407609	.00000000	.00000000	.00000000

TABLE B-6 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00028600	.01086958	.01358698	.01766297	.00000000	.00000000
22.500	.00017880	.00679349	.01222828	.00000000	.00000000	.00000000
45.000	.00017880	.00679349	.01222828	.00000000	.00000000	.00000000
67.500	.00010730	.00407609	.01494568	.00135870	.00000000	.00000000
90.000	.00025030	.00951089	.01086958	.00135870	.00000000	.00000000
112.500	.00014300	.00543479	.01358698	.00815219	.00000000	.00000000
135.000	.00017880	.00679349	.00815219	.00951089	.00000000	.00000000
157.500	.00010730	.00407609	.00407609	.00135870	.00000000	.00000000
180.000	.00017880	.00679349	.00543479	.00407609	.00000000	.00000000
202.500	.00003580	.00135870	.00679349	.00951089	.00271740	.00000000
225.000	.00157320	.00679349	.01494568	.01630428	.00543479	.00271740
247.500	.00021450	.00815219	.02038037	.02717386	.00679349	.00135870
270.000	.00171620	.01222828	.02445646	.05570642	.01358698	.00000000
292.500	.00010730	.00407609	.01766297	.02445646	.00679349	.00271740
315.000	.00282470	.00135870	.02173907	.02445646	.00407609	.00000000
337.500	.00007150	.00271740	.02038037	.01222828	.00000000	.00000000

TABLE B-6 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.01222828	.01766297	.00000000	.00000000	.00000000
22.500	.00000000	.00679349	.00679349	.00000000	.00000000	.00000000
45.000	.00000000	.00543479	.00271740	.00000000	.00000000	.00000000
67.500	.00000000	.00407609	.00679349	.00000000	.00000000	.00000000
90.000	.00000000	.01358698	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00407609	.00135870	.00000000	.00000000	.00000000
135.000	.00000000	.01086958	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00543479	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00679349	.00135870	.00000000	.00000000	.00000000
202.500	.00000000	.00135870	.00135870	.00000000	.00000000	.00000000
225.000	.00000000	.00815219	.00135870	.00000000	.00000000	.00000000
247.500	.00000000	.00135870	.00271740	.00000000	.00000000	.00000000
270.000	.00000000	.00271740	.00271740	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00407609	.00000000	.00000000	.00000000
315.000	.00000000	.00271740	.00407609	.00000000	.00000000	.00000000
337.500	.00000000	.00135870	.01358698	.00000000	.00000000	.00000000

TABLE B-6 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00513289	.00679349	.00000000	.00000000	.00000000	.00000000
22.500	.00450379	.00543479	.00000000	.00000000	.00000000	.00000000
45.000	.00324580	.00271740	.00000000	.00000000	.00000000	.00000000
67.500	.00251610	.00543479	.00000000	.00000000	.00000000	.00000000
90.000	.00387479	.00407609	.00000000	.00000000	.00000000	.00000000
112.500	.00397539	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00198770	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00198770	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00857989	.00135870	.00000000	.00000000	.00000000	.00000000
202.500	.00387479	.00407609	.00000000	.00000000	.00000000	.00000000
225.000	.00198770	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00659219	.00135870	.00000000	.00000000	.00000000	.00000000
270.000	.00774959	.00815219	.00000000	.00000000	.00000000	.00000000
292.500	.00324580	.00271740	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00188710	.00407609	.00000000	.00000000	.00000000	.00000000

TABLE B-7

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR SUMMER 1965

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00135870	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00135870	.00135870	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00135870	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-7 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00226450	.00407610	.00407610	.00000000	.00000000	.00000000
22.500	.00045290	.00271740	.00407610	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00271740	.00000000	.00000000	.00000000
67.500	.00022640	.00135870	.00000000	.00000000	.00000000	.00000000
90.000	.00113220	.00679349	.00135870	.00000000	.00000000	.00000000
112.500	.00022640	.00135870	.00135870	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00135870	.00000000	.00000000	.00000000
157.500	.00339670	.00135870	.00000000	.00000000	.00000000	.00000000
180.000	.00181160	.00135870	.00135870	.00000000	.00000000	.00000000
202.500	.00022640	.00135870	.00000000	.00000000	.00000000	.00000000
225.000	.00022640	.00135870	.00407610	.00000000	.00000000	.00000000
247.500	.00045290	.00271740	.00543479	.00000000	.00000000	.00000000
270.000	.00362320	.00271740	.00135870	.00000000	.00000000	.00000000
292.500	.00317030	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00158510	.00000000	.00407610	.00000000	.00000000	.00000000
337.500	.00022640	.00135870	.00135870	.00000000	.00000000	.00000000

TABLE B-7 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.6000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00035060	.00271740	.01494568	.00135870	.00000000	.00000000
22.500	.00052590	.00407610	.00271740	.00000000	.00000000	.00000000
45.000	.00035060	.00271740	.00407610	.00407610	.00000000	.00000000
67.500	.00035060	.00271740	.00543479	.00000000	.00000000	.00000000
90.000	.00017530	.00135870	.00543479	.00000000	.00000000	.00000000
112.500	.00017530	.00135870	.00000000	.00000000	.00000000	.00000000
135.000	.00017530	.00135870	.00407610	.00000000	.00000000	.00000000
157.500	.00035060	.00271740	.00135870	.00000000	.00000000	.00000000
180.000	.00070130	.00543479	.00815219	.00135870	.00000000	.00000000
202.500	.00188460	.00271740	.00000000	.00000000	.00135870	.00000000
225.000	.00035060	.00271740	.01086959	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00679349	.00135870	.00135870	.00000000
270.000	.00052590	.00407610	.00543479	.00815219	.00135870	.00000000
292.500	.00017530	.00135870	.01222829	.00407610	.00000000	.00000000
315.000	.00052590	.00407610	.00815219	.00000000	.00000000	.00000000
337.500	.00017530	.00135870	.00271740	.00135870	.00000000	.00000000

TABLE B-7 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00162380	.00407610	.02173908	.01086959	.00000000	.00000000
22.500	.00149130	.00135870	.00951089	.00407610	.00000000	.00000000
45.000	.00006630	.00135870	.00951089	.00135870	.00000000	.00000000
67.500	.00000000	.00000000	.00407610	.00679349	.00000000	.00000000
90.000	.00006630	.00135870	.00407610	.00271740	.00000000	.00000000
112.500	.00013260	.00271740	.00407610	.00271740	.00000000	.00000000
135.000	.00013260	.00271740	.00407610	.00000000	.00000000	.00000000
157.500	.00155750	.00271740	.00679349	.00000000	.00000000	.00000000
180.000	.00311510	.00543479	.00271740	.00679349	.00000000	.00000000
202.500	.00026510	.00543479	.01766296	.01086959	.00000000	.00000000
225.000	.00149130	.00135870	.03260667	.03940216	.00135870	.00000000
247.500	.00033140	.00679349	.01358699	.02309778	.00135870	.00000000
270.000	.00169010	.00543479	.02038038	.01766298	.00000000	.00000000
292.500	.00000000	.00000000	.00679349	.01358699	.00271740	.00000000
315.000	.00019880	.00407610	.01222829	.00951089	.00000000	.00000000
337.500	.00006630	.00135870	.01222829	.01086959	.00000000	.00000000

TABLE B-7 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00815219	.02717387	.00000000	.00000000	.00000000
22.500	.00000000	.00543479	.01086959	.00000000	.00000000	.00000000
45.000	.00000000	.00135870	.00679349	.00000000	.00000000	.00000000
67.500	.00000000	.00407610	.00271740	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00815219	.00135870	.00000000	.00000000	.00000000
135.000	.00000000	.00679349	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00679349	.00135870	.00000000	.00000000	.00000000
180.000	.00000000	.01086959	.00271740	.00000000	.00000000	.00000000
202.500	.00000000	.01630428	.00407610	.00000000	.00000000	.00000000
225.000	.00000000	.01222829	.01086959	.00000000	.00000000	.00000000
247.500	.00000000	.00679349	.00407610	.00000000	.00000000	.00000000
270.000	.00000000	.00543479	.00271740	.00000000	.00000000	.00000000
292.500	.00000000	.00679349	.00271740	.00000000	.00000000	.00000000
315.000	.00000000	.00407610	.00543479	.00000000	.00000000	.00000000
337.500	.00000000	.00135870	.00271740	.00000000	.00000000	.00000000

TABLE B-7 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00890699	.01222829	.00000000	.00000000	.00000000	.00000000
22.500	.00800119	.00679349	.00000000	.00000000	.00000000	.00000000
45.000	.00437800	.00407610	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00150970	.00271740	.00000000	.00000000	.00000000	.00000000
112.500	.00301930	.00543479	.00000000	.00000000	.00000000	.00000000
135.000	.00634059	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00573669	.00271740	.00000000	.00000000	.00000000	.00000000
180.000	.01011469	.00679349	.00000000	.00000000	.00000000	.00000000
202.500	.00362320	.00271740	.00000000	.00000000	.00000000	.00000000
225.000	.00875599	.00815219	.00000000	.00000000	.00000000	.00000000
247.500	.00452900	.00815219	.00000000	.00000000	.00000000	.00000000
270.000	.00226450	.00407610	.00000000	.00000000	.00000000	.00000000
292.500	.00724639	.00543479	.00000000	.00000000	.00000000	.00000000
315.000	.00437800	.00407610	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-8

JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES FOR FALL 1965

STABILITY CATEGORY 1

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00017170	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-8 (Continued)

STABILITY CATEGORY 2

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00137360	.00137360	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00137360	.00000000	.00000000	.00000000	.00000000
112.500	.00137360	.00000000	.00274730	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00137360	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00274730	.00137360	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00412090	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00137360	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00137360	.00000000	.00000000	.00000000
292.500	.00137360	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00137360	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-8 (Continued)

STABILITY CATEGORY 3

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00000000	.00412090	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00274730	.00686810	.00000000	.00000000	.00000000	.00000000
90.000	.00343410	.00137360	.00137360	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00412090	.00000000	.00000000	.00000000
135.000	.00206040	.00274730	.00000000	.00137360	.00000000	.00000000
157.500	.00045790	.00274730	.00412090	.00000000	.00000000	.00000000
180.000	.00022890	.00137360	.00412090	.00137360	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00824180	.00412090	.00000000	.00000000
247.500	.00022890	.00137360	.00000000	.00000000	.00000000	.00000000
270.000	.00160260	.00000000	.00549450	.00000000	.00000000	.00000000
292.500	.00022890	.00137360	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00137360	.00000000	.00000000	.00000000

TABLE B-8 (Continued)

STABILITY CATEGORY 4

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00038040	.00274730	.01785710	.00824180	.00000000	.00000000
22.500	.00076080	.00549450	.00412090	.00137360	.00000000	.00000000
45.000	.00019020	.00137360	.00274730	.00000000	.00000000	.00000000
67.500	.00057060	.00412090	.00686810	.00137360	.00000000	.00000000
90.000	.00076080	.00549450	.00824180	.00137360	.00000000	.00000000
112.500	.00095100	.00686810	.01236260	.00412090	.00000000	.00000000
135.000	.00076080	.00549450	.01098900	.00824180	.00000000	.00000000
157.500	.00038040	.00274730	.00274730	.00824180	.00000000	.00000000
180.000	.00114120	.00824180	.01510990	.01236260	.00000000	.00000000
202.500	.00038040	.00274730	.00824180	.02197800	.00000000	.00000000
225.000	.00289520	.00961540	.03296701	.05906591	.00549450	.00000000
247.500	.00251480	.00686810	.02335160	.03021981	.00686810	.00824180
270.000	.00076080	.00549450	.04120881	.04258241	.00961540	.00000000
292.500	.00057060	.00412090	.01098900	.01785710	.00686810	.00274730
315.000	.00445900	.00961540	.00961540	.01236260	.00137360	.00137360
337.500	.00038040	.00274730	.00549450	.00686810	.00000000	.00000000

TABLE B-8 (Continued)

STABILITY CATEGORY 5

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00000000	.00274730	.00274730	.00000000	.00000000	.00000000
22.500	.00000000	.00549450	.00274730	.00000000	.00000000	.00000000
45.000	.00000000	.00274730	.00137360	.00000000	.00000000	.00000000
67.500	.00000000	.00686810	.00137360	.00000000	.00000000	.00000000
90.000	.00000000	.00824180	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00274730	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00824180	.00274730	.00000000	.00000000	.00000000
157.500	.00000000	.00137360	.00137360	.00000000	.00000000	.00000000
180.000	.00000000	.00549450	.00137360	.00000000	.00000000	.00000000
202.500	.00000000	.00137360	.00686810	.00000000	.00000000	.00000000
225.000	.00000000	.00137360	.00686810	.00000000	.00000000	.00000000
247.500	.00000000	.00137360	.00274730	.00000000	.00000000	.00000000
270.000	.00000000	.00961540	.00549450	.00000000	.00000000	.00000000
292.500	.00000000	.00137360	.00549450	.00000000	.00000000	.00000000
315.000	.00000000	.00137360	.00412090	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

TABLE B-8 (Continued)

STABILITY CATEGORY 6

DIRECTION (PHI DEGREES)	WIND SPEED CATEGORY 1 (.7500MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
.000	.00582660	.00549450	.00000000	.00000000	.00000000	.00000000
22.500	.00623420	.00961540	.00000000	.00000000	.00000000	.00000000
45.000	.00582660	.00549450	.00000000	.00000000	.00000000	.00000000
67.500	.00356240	.00549450	.00000000	.00000000	.00000000	.00000000
90.000	.01933640	.01236260	.00000000	.00000000	.00000000	.00000000
112.500	.00671720	.00686810	.00000000	.00000000	.00000000	.00000000
135.000	.00946440	.00412090	.00000000	.00000000	.00000000	.00000000
157.500	.01124560	.00686810	.00000000	.00000000	.00000000	.00000000
180.000	.01254360	.01236260	.00000000	.00000000	.00000000	.00000000
202.500	.00267180	.00412090	.00000000	.00000000	.00000000	.00000000
225.000	.00582660	.00549450	.00000000	.00000000	.00000000	.00000000
247.500	.00582660	.00549450	.00000000	.00000000	.00000000	.00000000
270.000	.00698140	.00686810	.00000000	.00000000	.00000000	.00000000
292.500	.00630960	.00274730	.00000000	.00000000	.00000000	.00000000
315.000	.00039060	.00137360	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

APPENDIX C

DESCRIPTION OF DIFFUSION-MODEL COMPUTER PROGRAMS AND EXPLANATION OF COMPUTER PRINTOUT

C.1 General

The atmospheric diffusion models described in Appendix A and used in this study to calculate ground-level SO_2 concentration patterns within Allegheny County are contained in two computer programs:

- The short-term models for calculating 1-hour, 3-hour and 24-hour concentrations are contained in a computer program entitled SHORT Z
- The long-term models for calculating seasonal and annual concentrations are contained in a separate computer program entitled LONG Z

Both programs provide for calculating, at each grid point, the concentration contributed by each source, source complex and all sources combined. In the case of the SHORT Z program, 1-hour, 3-hour and 24-hour average concentrations may be calculated. In the case of the LONG Z program, seasonal and annual concentrations may be calculated.

The results of all the concentration calculations made using the SHORT Z and LONG Z programs, as well as detailed listings of all meteorological data, source data, grid-point locations and terrain-elevation data, have been forwarded to EPA in the form of twenty-five bound volumes containing 30,500 pages of computer printout. Additionally, all of the model inputs and the results of the LONG Z program calculations are maintained in a master file on magnetic tape. The LONG

Z program has the unique capability of updating the emissions data for a single source or group of sources and of recalculating the effects of such changes at each grid point without repeating all of the original calculations. This updating feature not only results in considerable savings in computer costs but also provides an effective means of maintaining a complete up-to-date file of emissions inventory data and long-term concentration data.

The computer printout sheets supplied to EPA include the following specific diffusion-model calculations:

- Annual average SO_2 ground-level concentrations within Allegheny County for 1973 and for Compliance Case A emissions data (using meteorological data for 1965)
- One-hour, 3-hour and 24-hour SO_2 ground-level concentrations for the 4 January 1973 air pollution episode at Logans Ferry, the 18 January 1973 and 13 July 1973 air pollution episodes are Liberty Borough, and for Compliance Case A emissions (using worst-case 24-hour meteorology)

Additional details of the computer programs and explanation of the computer printout formats are given below.

C.2 DESCRIPTION OF THE SHORT-TERM DIFFUSION-MODEL COMPUTER PROGRAM — SHORT Z

C.2.1 Program Capabilities

The computer program containing the short-term diffusion models, which is entitled SHORT Z, is written in Fortran IV and is designed to calculate

1-hour, 3-hour, 8-hour and 24-hour ground-level pollutant concentrations at a large number of grid or receptor points. The program accepts a maximum of 120 individual sources and a maximum of 16,500 grid points. Sources are classified in three basic categories (stack, building and area). It is not necessary to separate the three types of sources for input to SHORT Z; sources can be input in any sequence. A Cartesian coordinate system (normally the Universal Transverse Mercator system, UTM) is used to define the calculation grid with the positive x-axis directed toward the east (90 degrees) and the positive y-axis directed toward the north (0 or 360 degrees). The method of assigning grid-point locations is unrestricted; a regular grid array with uniform spacings of points may be used alone or in combination with an array of discrete points.

The short-term model program calculates the total ground-level pollutant concentration at each grid point resulting from all sources by first calculating the contribution from each source independently for each basic time period, usually 1 hour or 3 hours, specified by the input data. The results of these calculations are then combined to obtain the concentrations at each grid point resulting from each individual source independently, from selected groups of sources and from all sources combined for the specific time periods given in the program input statements.

All calculations using the short-term diffusion-model program were made at the University of Utah Computer Center on a UNIVAC 1108 central processor. The operating time for the SHORT Z program may be estimated from the expression

$$\text{Operating time in seconds} = RP \times NS \times H \times 0.003$$

where RP is the number of grid points, NS is the number of sources and H is the number of hours or time-periods for which basic meteorological data are available.

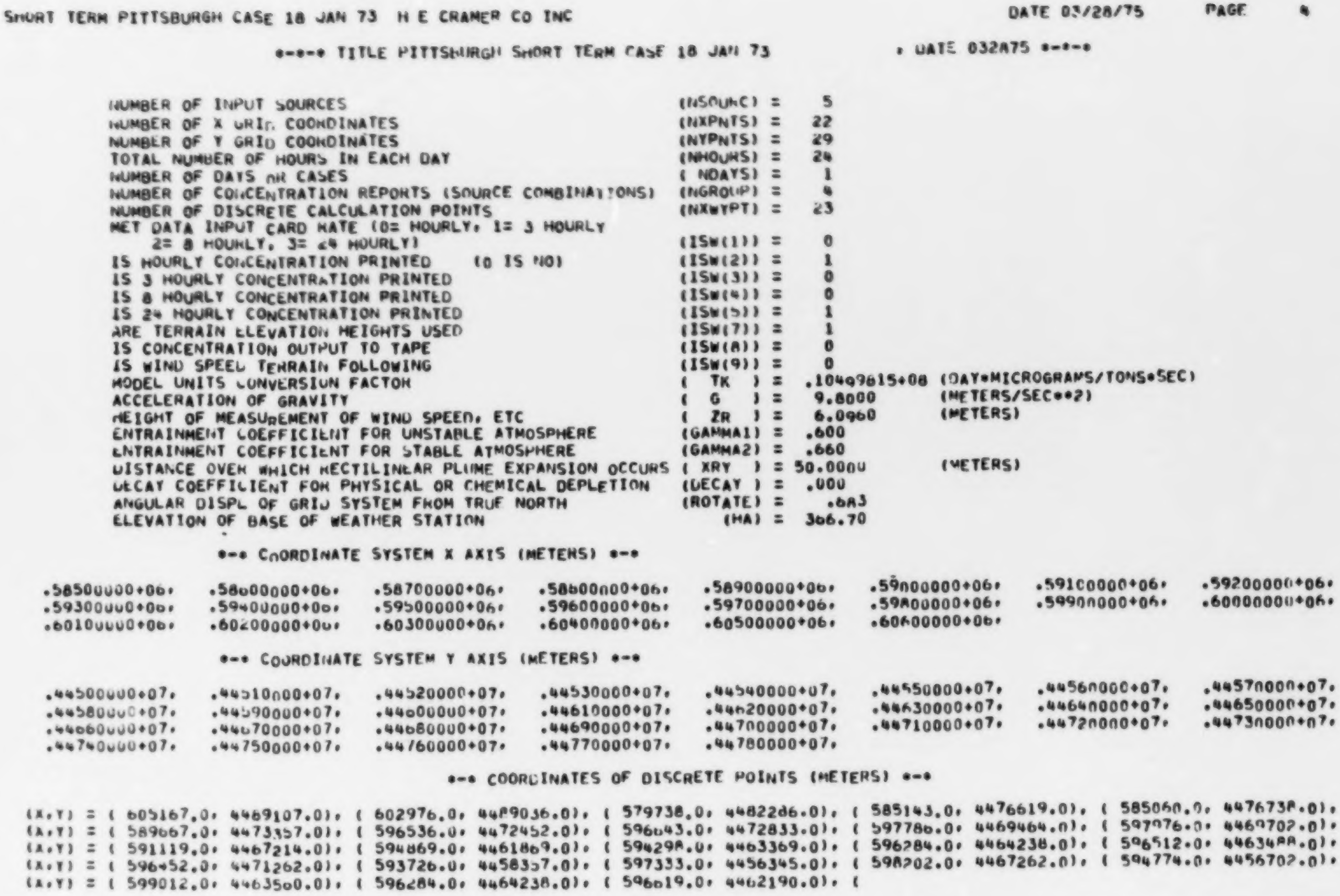
C.2.2 Program Input Listings

In addition to the program operating and control statements, the short-term diffusion models require that the following input information be supplied:

- Coordinates and terrain elevations of all grid point locations
- Coordinates and terrain elevations of all sources
- Emission rates for all sources
- Stack data and other source parameters for all sources
- Meteorological parameters

All of the operating, control and input information is listed in the computer program output. Figure C-1 is an example output page produced by the SHORT Z program. The information printed at the top of the figure gives the operating instructions and constants provided as input to the program. The three tables at the bottom of the figure list the locations of all grid points. The tables that are labeled "Coordinate System X Axis" and "Coordinate System Y Axis" give the UTM X and Y coordinates for a regularly-spaced grid system given by the intersections of the UTM X and Y coordinates. These grid points are automatically assigned by the program. The table "Coordinates of Discrete Points" lists the UTM coordinates for grid points not included in the regular array. Discrete points are used to calculate ground-level concentrations at specific points such as the locations of air quality monitors. Figures C-2 and C-3 show example listings of grid-point elevations (terrain heights) above mean sea level for the regular grid and the discrete-point grid, respectively.

Figure C-4 is a printout sheet listing the source data input to the SHORT Z program. The first column at the left of the page lists the source numbers. In the



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                    *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73              * DATE 032875 *-*-*

        NUMBER OF INPUT SOURCES                                       (NSOURC) =    5
        NUMBER OF X GRID COORDINATES                                  (NXPNTS) =   22
        NUMBER OF Y GRID COORDINATES                                  (NYPNTS) =   29
        TOTAL NUMBER OF HOURS IN EACH DAY                             (NHOURS) =   24
        NUMBER OF DAYS OR CASES                                       ( NDAYS) =    1
        NUMBER OF CONCENTRATION REPORTS (SOURCE COMBINATIONS)         (NGROUP) =    4
        NUMBER OF DISCRETE CALCULATION POINTS                         (NXWYPT) =   23
        MET DATA INPUT CARD RATE (0= HOURLY, 1= 3 HOURLY
            2= 8 HOURLY, 3= 24 HOURLY)                                (ISW(1)) =    0
        IS HOURLY CONCENTRATION PRINTED    (0 IS NO)                  (ISW(2)) =    1
        IS 3 HOURLY CONCENTRATION PRINTED                             (ISW(3)) =    0
        IS 8 HOURLY CONCENTRATION PRINTED                             (ISW(4)) =    0
        IS 24 HOURLY CONCENTRATION PRINTED                            (ISW(5)) =    1
        ARE TERRAIN ELEVATION HEIGHTS USED                            (ISW(7)) =    1
        IS CONCENTRATION OUTPUT TO TAPE                               (ISW(8)) =    0
        IS WIND SPEED TERRAIN FOLLOWING                               (ISW(9)) =    0
        MODEL UNITS CONVERSION FACTOR                                 (  TK  ) = .10409615+08 (DAY*MICROGRAMS/TONS*SEC)
        ACCELERATION OF GRAVITY                                       (  G   ) =  9.8000      (METERS/SEC**2)
        HEIGHT OF MEASUREMENT OF WIND SPEED, ETC                      (  ZR  ) =  6.0960      (METERS)
        ENTRAINMENT COEFFICIENT FOR UNSTABLE ATMOSPHERE               (GAMMA1) =  .600
        ENTRAINMENT COEFFICIENT FOR STABLE ATMOSPHERE                 (GAMMA2) =  .660
        DISTANCE OVER WHICH RECTILINEAR PLUME EXPANSION OCCURS        ( XRY  ) = 50.0000      (METERS)
        DECAY COEFFICIENT FOR PHYSICAL OR CHEMICAL DEPLETION          (DECAY ) =  .000
        ANGULAR DISPL OF GRID SYSTEM FROM TRUE NORTH                  (ROTATE) =    .683
        ELEVATION OF BASE OF WEATHER STATION                              (HA) =  366.70

                    *-* COORDINATE SYSTEM X AXIS (METERS) *-*

  .58500000+06,   .58600000+06,   .58700000+06,   .58600000+06,   .58900000+06,   .59000000+06,   .59100000+06,   .59200000+06,
  .59300000+06,   .59400000+06,   .59500000+06,   .59600000+06,   .59700000+06,   .59800000+06,   .59900000+06,   .60000000+06,
  .60100000+06,   .60200000+06,   .60300000+06,   .60400000+06,   .60500000+06,   .60600000+06,

                    *-* COORDINATE SYSTEM Y AXIS (METERS) *-*

  .44500000+07,   .44510000+07,   .44520000+07,   .44530000+07,   .44540000+07,   .44550000+07,   .44560000+07,   .44570000+07,
  .44580000+07,   .44590000+07,   .44600000+07,   .44610000+07,   .44620000+07,   .44630000+07,   .44640000+07,   .44650000+07,
  .44660000+07,   .44670000+07,   .44680000+07,   .44690000+07,   .44700000+07,   .44710000+07,   .44720000+07,   .44730000+07,
  .44740000+07,   .44750000+07,   .44760000+07,   .44770000+07,   .44780000+07,

                              *-* COORDINATES OF DISCRETE POINTS (METERS) *-*

(X,Y) = ( 605167.0, 4469107.0), ( 602976.0, 4489036.0), ( 579738.0, 4482286.0), ( 585143.0, 4476619.0), ( 585060.0, 4476738.0),
(X,Y) = ( 589667.0, 4473357.0), ( 596536.0, 4472452.0), ( 596643.0, 4472833.0), ( 597786.0, 4469464.0), ( 597976.0, 4469702.0),
(X,Y) = ( 591119.0, 4467214.0), ( 594869.0, 4461869.0), ( 594298.0, 4463369.0), ( 596284.0, 4464238.0), ( 596512.0, 4463488.0),
(X,Y) = ( 596452.0, 4471262.0), ( 593726.0, 4458357.0), ( 597333.0, 4456345.0), ( 598202.0, 4467262.0), ( 594774.0, 4456702.0),
(X,Y) = ( 599012.0, 4463560.0), ( 596284.0, 4464238.0), ( 596619.0, 4462190.0), (
```

FIGURE C-1. Example printout sheet from the SHORT Z program listing program operating instructions, values of constants used in the calculations, and UTM coordinates of all grid points.

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                    *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73             DATE 032875 *-*-*

                                               *-* GRID SYSTEM TERRAIN HEIGHTS (METERS) *-*

                                                        - X AXIS (METERS) -
                 585000.000   586000.000   587000.000   588000.000   589000.000   590000.000   591000.000   592000.000   593000.000
Y AXIS (METERS)                                                  - HEIGHT -
                 ---------------------------------------------------------------------------------------------------------------

  4478000.000   226.0000000  226.0000000  347.0000000  354.0000000  277.0000000  280.0000000  314.0000000  305.0000000  299.0000000
  4477000.000   229.0000000  274.0000000  287.0000000  308.0000000  256.0000000  317.0000000  335.0000000  341.0000000  302.0000000
  4476000.000   216.0000000  216.0000000  219.0000000  223.0000000  232.0000000  311.0000000  332.0000000  347.0000000  296.0000000
  4475000.000   351.0000000  317.0000000  268.0000000  232.0000000  235.0000000  329.0000000  323.0000000  314.0000000  256.0000000
  4474000.000   317.0000000  360.0000000  323.0000000  320.0000000  232.0000000  277.0000000  363.0000000  216.0000000  223.0000000
  4473000.000   341.0000000  335.0000000  271.0000000  354.0000000  216.0000000  265.0000000  274.0000000  235.0000000  277.0000000
  4472000.000   274.0000000  366.0000000  329.0000000  347.0000000  335.0000000  219.0000000  226.0000000  305.0000000  299.0000000
  4471000.000   296.0000000  347.0000000  363.0000000  375.0000000  360.0000000  341.0000000  341.0000000  317.0000000  332.0000000
  4470000.000   360.0000000  311.0000000  372.0000000  369.0000000  305.0000000  259.0000000  305.0000000  335.0000000  329.0000000
  4469000.000   323.0000000  366.0000000  372.0000000  335.0000000  332.0000000  363.0000000  341.0000000  347.0000000  335.0000000
  4468000.000   347.0000000  369.0000000  347.0000000  335.0000000  274.0000000  366.0000000  335.0000000  335.0000000  369.0000000
  4467000.000   357.0000000  372.0000000  344.0000000  320.0000000  366.0000000  372.0000000  378.0000000  332.0000000  311.0000000
  4466000.000   335.0000000  329.0000000  354.0000000  369.0000000  366.0000000  372.0000000  323.0000000  351.0000000  335.0000000
  4465000.000   351.0000000  305.0000000  326.0000000  338.0000000  326.0000000  351.0000000  354.0000000  320.0000000  287.0000000
  4464000.000   335.0000000  326.0000000  317.0000000  347.0000000  360.0000000  299.0000000  354.0000000  335.0000000  293.0000000
  4463000.000   317.0000000  317.0000000  329.0000000  363.0000000  384.0000000  287.0000000  323.0000000  329.0000000  308.0000000
  4462000.000   305.0000000  347.0000000  280.0000000  354.0000000  351.0000000  332.0000000  290.0000000  323.0000000  317.0000000
  4461000.000   347.0000000  311.0000000  329.0000000  366.0000000  347.0000000  323.0000000  320.0000000  274.0000000  250.0000000
  4460000.000   305.0000000  299.0000000  329.0000000  293.0000000  274.0000000  293.0000000  293.0000000  268.0000000  317.0000000
  4459000.000   335.0000000  317.0000000  268.0000000  265.0000000  280.0000000  268.0000000  338.0000000  320.0000000  305.0000000
  4458000.000   338.0000000  290.0000000  262.0000000  308.0000000  338.0000000  335.0000000  250.0000000  329.0000000  253.0000000
  4457000.000   311.0000000  296.0000000  326.0000000  351.0000000  320.0000000  323.0000000  317.0000000  232.0000000  223.0000000
  4456000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
  4455000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
  4454000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
  4453000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
  4452000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
  4451000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
  4450000.000   305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000  305.0000000
```

FIGURE C-2. Example printout sheet from the SHORT Z computer program listing terrain heights of the grid points in the regular array.

```
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                              *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73            . DATE 032875 *-*-*

                                                    *-* GRID SYSTEM TERRAIN HEIGHTS (METERS) *-*

     X          Y           HEIGHT                 X          Y           HEIGHT                 X          Y           HEIGHT
           ----------------------------------------------------------------------------------------------------------------------

 605167.0   4489107.0    274.0000000          602976.0   4489036.0    305.0000000          579738.0   4482286.0    232.0000000
 585143.0   4476619.0    232.0000000          585060.0   4476738.0    235.0000000          589667.0   4473357.0    244.0000000
 596536.0   4472452.0    232.0000000          596643.0   4472833.0    265.0000000          597786.0   4469464.0    265.0000000
 597976.0   4469702.0    235.0000000          591119.0   4467214.0    381.0000000          594869.0   4461869.0    226.0000000
 594298.0   4463369.0    232.0000000          596284.0   4464238.0    323.0000000          596512.0   4463488.0    354.0000000
 596452.0   4471262.0    274.0000000          593726.0   4458357.0    231.0000000          597333.0   4456345.0    357.0000000
 598202.0   4467262.0    232.0000000          594774.0   4456702.0    354.0000000          599012.0   4463560.0    253.0000000
 596284.0   4464238.0    326.0000000          596619.0   4462190.0    323.0000000
```

FIGURE C-3. Example printout sheet from the SHORT Z program listing terrain heights for grid points in the discrete array.

```
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                                 *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73          * DATE 032875 *-*-*

SOURCE T   SOURCE        X           Y         HEIGHT   IF TYPE=0     IF TYPE=0     ANGLE   STACK    ELEVATION   PARTICLE    DISTRIBUTION
NUMBER Y  STRENGTH   COORDINATE  COORDINATE    ABOVE    TEMP (DEG K)  VOL. EMISS.    TO    INTERNAL     AT       SETTLING     FREQUENCY
       P (TONS/DAY)   (METERS)    (METERS)     GROUND   IF TYPE=1OR2  RT. M**3/SEC  LONG    RADIUS     STACK      VELOCITY        OF
       E                                      (METERS)  LENGTH SHORT  IF TYPE=1OR2  SIDE   (METERS)    BASE    (METERS/SEC)  OCCURRENCE
                                                        SIDE (MTRS)   LENGTH LONG   (DEG)             (METERS)
                                                                      SIDE (MTRS)
     1 0          1.16 595860.00  4461520.00     69.00      700.000       37.270      .00     1.22     229.00
     2 0          1.16 595830.00  4461540.00     69.00      700.000       37.270      .00     1.22     229.00
     3 0          1.16 595730.00  4461780.00     69.00      700.000       37.270      .00     1.22     229.00
     7 0          1.16 595880.00  4461650.00     65.00      700.000       35.870      .00     1.27     229.00
     8 0          1.16 595870.00  4461680.00     65.00      700.000       35.870      .00     1.27     229.00
```

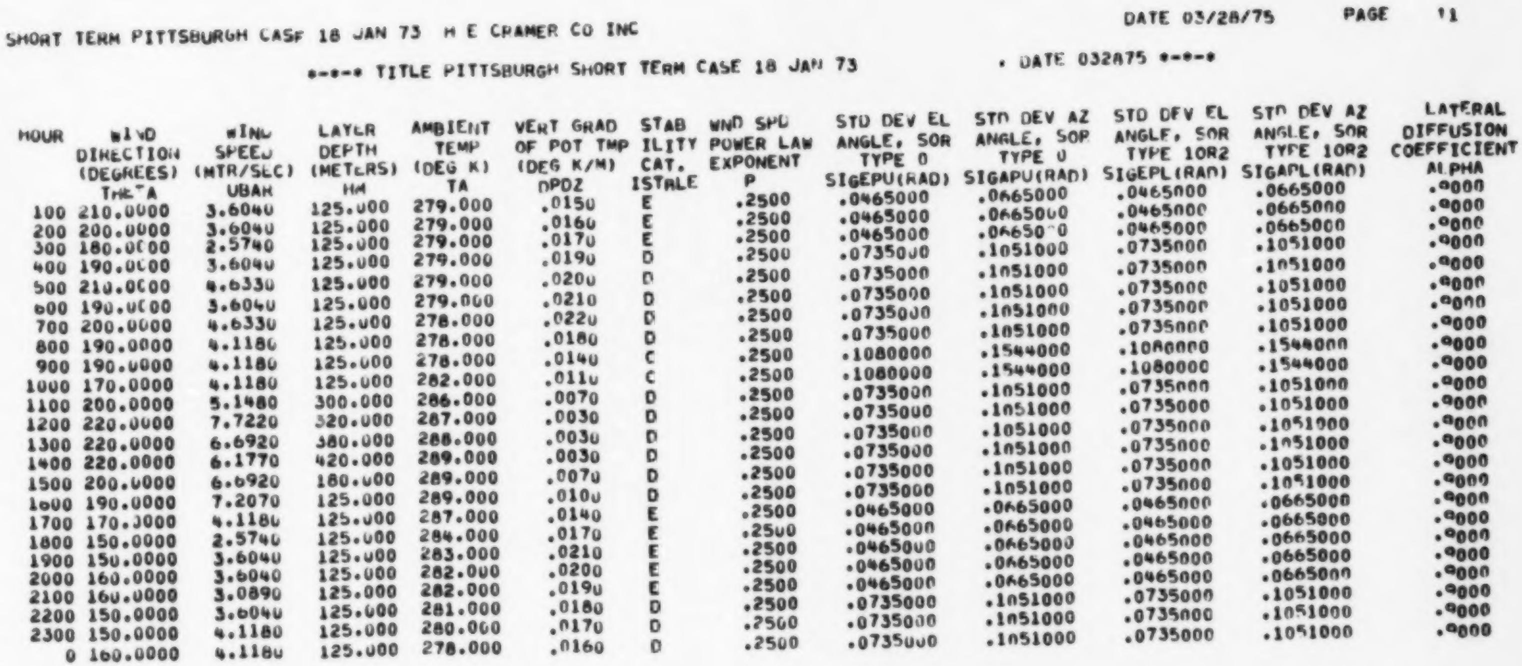
FIGURE C-4. Example printout sheet from the SHORT Z computer program listing input source data.

second column from the left, each source is assigned a code number that classifies the source into one of three basic categories:

- 0 - Stack
- 1 - Building
- 2 - Area

The third column from the left gives the source strength (pollutant emission rate) in tons per day for each source. The next two columns give the UTM coordinates for each source. The sixth column from the left gives the stack height above grade in meters. For a building source, this column gives the building height; for an area source, this column gives the characteristic emission height. For a stack, the next two columns give the exit temperature of the stack gas in degrees Kelvin and the actual volumetric emission rate of the stack in cubic meters per second. For building and area sources, these columns give the source width and length. Column 9 gives the deviation in degrees of the long side of the building or area source from north; this column is not used for a stack. Column 10 gives the internal radius of the stack in meters and Column 11 gives the elevation above mean sea level of the base of the stack or building. The last two columns of the printout, which provide information used to calculate ground-level concentrations when there is significant gravitational settling, are not applicable to this report.

As with the source input parameters, the SHORT Z program prints a listing of meteorological inputs used in the calculations. Figure C-5 gives an example table of meteorological inputs. The first column from the left gives the hour, the second column gives the wind direction in degrees, the third column gives the airport wind speed in meters per second, the fourth column gives the mixing depth in meters, the fifth column gives the ambient air temperature in degrees Kelvin, the sixth column gives the vertical poetntial temperature gradient, the seventh column gives the stability category and the eighth column gives the wind-



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                           *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73          . DATE 032875 *-*-*

HOUR    WIND       WIND      LAYER    AMBIENT   VERT GRAD  STAB  WND SPD    STD DEV EL   STD DEV AZ   STD DEV EL   STD DEV AZ       LATERAL
     DIRECTION    SPEED      DEPTH      TEMP    OF POT TMP ILITY POWER LAW  ANGLE, SOR   ANGLE, SOR   ANGLE, SOR   ANGLE, SOR      DIFFUSION
     (DEGREES)  (MTR/SEC)  (METERS)  (DEG K)   (DEG K/M)  CAT.  EXPONENT     TYPE 0       TYPE 0     TYPE 1OR2    TYPE 1OR2     COEFFICIENT
       THETA       UBAR        HM        TA        DPDZ    ISTALE    P      SIGEPU(RAD)  SIGAPU(RAD)  SIGEPL(RAD)  SIGAPL(RAD)        ALPHA
 100 210.0000     3.6040    125.000   279.000     .0150     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
 200 200.0000     3.6040    125.000   279.000     .0160     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
 300 180.0000     2.5740    125.000   279.000     .0170     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
 400 190.0000     3.6040    125.000   279.000     .0190     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
 500 210.0000     4.6330    125.000   279.000     .0200     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
 600 190.0000     3.6040    125.000   279.000     .0210     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
 700 200.0000     4.6330    125.000   278.000     .0220     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
 800 190.0000     4.1180    125.000   278.000     .0180     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
 900 190.0000     4.1180    125.000   278.000     .0140     C       .2500     .1080000     .1544000     .1080000     .1544000          .9000
1000 170.0000     4.1180    125.000   282.000     .0110     C       .2500     .1080000     .1544000     .1080000     .1544000          .9000
1100 200.0000     5.1480    300.000   286.000     .0070     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
1200 220.0000     7.7220    320.000   287.000     .0030     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
1300 220.0000     6.6920    380.000   288.000     .0030     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
1400 220.0000     6.1770    420.000   289.000     .0030     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
1500 200.0000     6.6920    180.000   289.000     .0070     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
1600 190.0000     7.2070    125.000   289.000     .0100     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
1700 170.0000     4.1180    125.000   287.000     .0140     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
1800 150.0000     2.5740    125.000   284.000     .0170     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
1900 150.0000     3.6040    125.000   283.000     .0210     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
2000 160.0000     3.6040    125.000   282.000     .0200     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
2100 160.0000     3.0890    125.000   282.000     .0190     E       .2500     .0465000     .0665000     .0465000     .0665000          .9000
2200 150.0000     3.6040    125.000   281.000     .0180     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
2300 150.0000     4.1180    125.000   280.000     .0170     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
   0 160.0000     4.1180    125.000   278.000     .0160     D       .2500     .0735000     .1051000     .0735000     .1051000          .9000
```

FIGURE C-5. Example printout sheet from the SHORT Z computer program listing meteorological inputs.

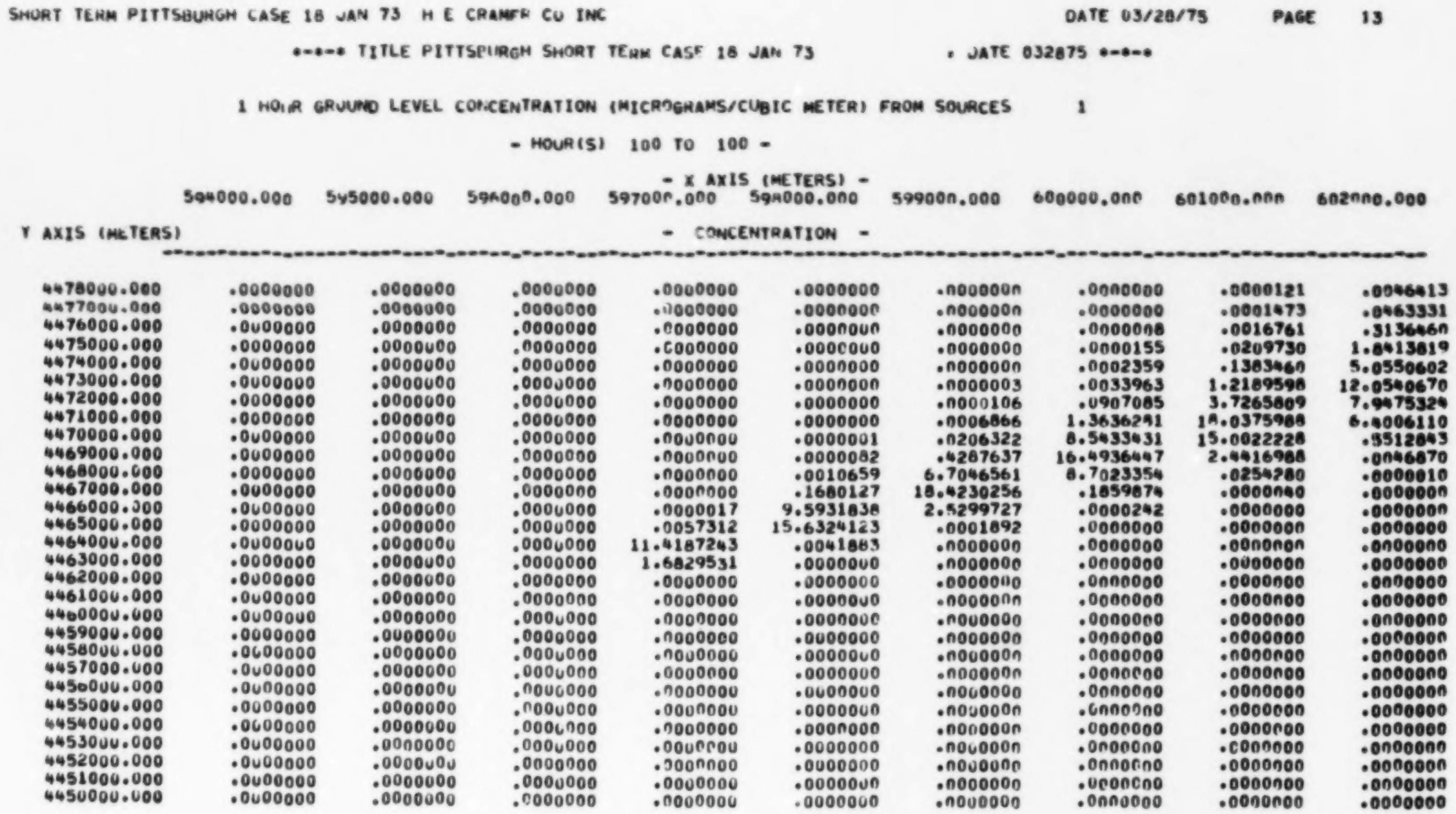
profile exponent. The next four columns give the standard deviations in radians of the wind azimuth and elevation angles for elevated (stack) and low-level (building and area) sources. Section 3 of the main body of the report discusses the specification of these meteorological inputs.

C.2.3 Program Output Listing

At each grid point, the SHORT Z program calculates the ground-level concentration for each hour resulting from emissions from each source. Figures C-6 and C-7 show example printout sheets of calculated hourly ground-level concentrations in micrograms per cubic meter for a regularly-spaced grid and a discrete-point grid, respectively. In Figure C-6, the X coordinates are listed across the top of the page and the Y coordinates are listed in the extreme left-hand column. As shown by Figure C-7, the concentrations calculated for the discrete points are given following the X and Y coordinates of the points. In both figures, the source number is printed at the top of the page. Additionally, the concentration averaging time and the corresponding hours are shown at the top center of the page.

Figures C-8 and C-9 show example printout sheets of calculated 24-hour average ground-level concentrations for a regularly-spaced grid and for a discrete-point grid, respectively. Because the hours in Figure C-5 are numbered 0100 to 0000, the averaging period for the 24-hour period is labeled "HOUR(S) 100 to 0" in Figures C-8 and C-9. In addition to hourly and 24-hour average concentrations, the SHORT Z program has the capability of calculating 3-hour and 8-hour concentrations.

The SHORT Z program can calculate the short-term ground-level concentrations produced by all sources combined or by any combination of the sources. Thus, it is easy to determine the contributions of the individual source complexes to the total calculated concentrations. Figures C-10 and C-11 show example printout sheets



```
SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                   DATE 03/28/75      PAGE    13
                      *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73            , DATE 032875 *-*-*

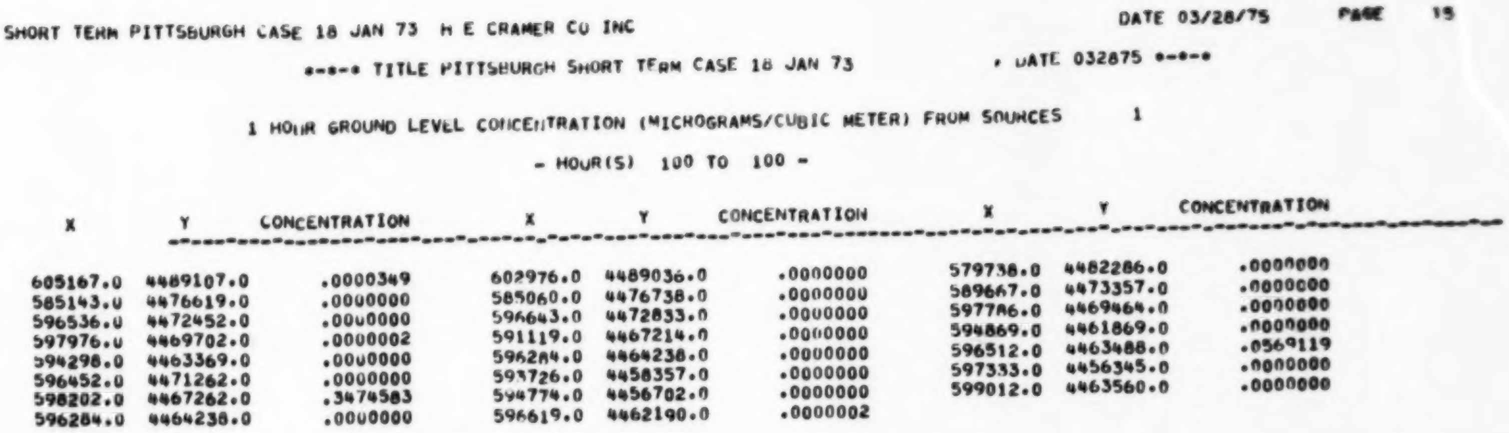
                  1 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES       1

                                               - HOUR(S)  100 TO  100 -

                                                    - X AXIS (METERS) -
                594000.000    595000.000    596000.000    597000.000    598000.000    599000.000    600000.000    601000.000    602000.000
 Y AXIS (METERS)                                             - CONCENTRATION  -
                ------------------------------------------------------------------------------------------------------------------------

  4478000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000121      .0046413
  4477000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0001473      .0463331
  4476000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000008      .0016761      .3136460
  4475000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000155      .0209730     1.8413819
  4474000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0002359      .1383460     5.0550602
  4473000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000003      .0033963     1.2189598    12.0540670
  4472000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000106      .0907085     3.7265809     7.9475324
  4471000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0006866     1.3636291    18.0375988     6.4006110
  4470000.000     .0000000      .0000000      .0000000      .0000000      .0000001      .0206322     8.5433431    15.0022228      .5512843
  4469000.000     .0000000      .0000000      .0000000      .0000000      .0000082      .4287637    16.4936447     2.4416988      .0046870
  4468000.000     .0000000      .0000000      .0000000      .0000000      .0010659     6.7046561     8.7023354      .0254280      .0000010
  4467000.000     .0000000      .0000000      .0000000      .0000000      .1680127    18.4230256      .1859874      .0000040      .0000000
  4466000.000     .0000000      .0000000      .0000000      .0000017     9.5931838     2.5299727      .0000242      .0000000      .0000000
  4465000.000     .0000000      .0000000      .0000000      .0057312    15.6324123      .0001892      .0000000      .0000000      .0000000
  4464000.000     .0000000      .0000000      .0000000    11.4187243      .0041883      .0000000      .0000000      .0000000      .0000000
  4463000.000     .0000000      .0000000      .0000000     1.6829531      .0000000      .0000000      .0000000      .0000000      .0000000
  4462000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4461000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4460000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4459000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4458000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4457000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4456000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4455000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4454000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4453000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4452000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4451000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
  4450000.000     .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
```

FIGURE C-6. Example printout sheet from the SHORT Z computer program listing 1-hour ground-level concentrations from Source 1 calculated at all grid points of the regular array.



```
SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                        DATE 03/28/75      PAGE    15
                                  *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73          , DATE 032875 *-*-*

                          1 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES      1

                                                  - HOUR(S)  100 TO  100 -

    X          Y       CONCENTRATION            X          Y       CONCENTRATION            X          Y       CONCENTRATION
           ------------------------------------------------------------------------------------------------------------------------

605167.0  4489107.0       .0000349          602976.0  4489036.0       .0000000          579738.0  4482286.0       .0000000
585143.0  4476619.0       .0000000          585060.0  4476738.0       .0000000          589667.0  4473357.0       .0000000
596536.0  4472452.0       .0000000          596643.0  4472833.0       .0000000          597786.0  4469464.0       .0000000
597976.0  4469702.0       .0000002          591119.0  4467214.0       .0000000          594869.0  4461869.0       .0000000
594298.0  4463369.0       .0000000          596284.0  4464238.0       .0000000          596512.0  4463488.0       .0569119
596452.0  4471262.0       .0000000          593726.0  4458357.0       .0000000          597333.0  4456345.0       .0000000
598202.0  4467262.0       .3474583          594774.0  4456702.0       .0000000          599012.0  4463560.0       .0000000
596284.0  4464238.0       .0000000          596619.0  4462190.0       .0000002
```

FIGURE C-7. Example printout sheet from the SHORT Z computer program listing 1-hour ground-level concentrations from Source 1 calculated at all discrete grid points.

```
SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                          DATE 03/28/75      PAGE   109
                              *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73            . DATE 032875 *-*-*

                    24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES      1

                                                 - HOUR(S)  100 TO     0 -

                                                               - X AXIS (METERS) -
              594000.000   595000.000   596000.000   597000.000   598000.000   599000.000   600000.000   601000.000   602000.000

Y AXIS (METERS)                                              - CONCENTRATION -
          -----------------------------------------------------------------------------------------------------------------------

 4478000.000    .1696406     .3751610     .7987491     .7434532    1.0949574    1.3765536     .7944918     .7608455     .6361767
 4477000.000    .1929388     .3953894     .7918494     .8354397    1.2446707    1.0834176     .6313994     .8977503     .7097655
 4476000.000    .2314955     .3564363     .9102026     .9519625    1.6294191    1.1465207     .8158549     .9425779     .5661799
 4475000.000    .3104705     .3898644     .8090999     .7616007    1.8646240     .9397271     .9841974     .9934288     .5357818
 4474000.000    .3099595     .2946372     .6418161    1.0941309    1.2469132     .8143035     .9524521     .5570962     .5215611
 4473000.000    .5586123     .2347740     .5549557    1.4623749    1.7573038     .8016755     .8070644     .5047118     .8540183
 4472000.000    .5723031     .3792312     .5644877     .8753067    1.2920607     .8417409    1.0838295     .4007039     .5508025
 4471000.000    .8433035     .3599227     .9494208    1.0909759    1.1999278    1.6382184     .9219068    1.2525357     .6423834
 4470000.000   1.1552424     .4206295    1.1753744    1.7382635    1.0286901    1.3907349     .9350021    1.0990139     .3687892
 4469000.000    .7285478     .5043561    1.4344518    2.4168599    1.2299315     .7517208    1.1313433     .4915939     .3740345
 4468000.000   1.2176959     .7475135    1.5882804    2.5202315    1.4109287     .7998521     .8016656     .4037369     .1944952
 4467000.000   2.2226021     .7505549    1.0728407    2.2063670    1.5983561    1.2698533     .4342364     .2511548     .0296432
 4466000.000   2.2267682    1.6905537    1.8131068    2.5020328    1.3125092     .6840045     .3524035     .0227907     .0004348
 4465000.000   2.8056163    1.9789464    2.6515557    3.2364039    1.2868801     .5186685     .0201394     .0000869     .0000001
 4464000.000    .8352695    6.3631001    4.0628141    2.4699895    1.0833874     .0108854     .0000042     .0000000     .0000000
 4463000.000    .0000196   10.4475714    8.6234735    3.6728496     .0022578     .0000000     .0000000     .0000000     .0000000
 4462000.000    .0000000     .0000000     .3950879     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4461000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4460000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4459000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4458000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4457000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4456000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4455000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4454000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4453000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4452000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4451000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
 4450000.000    .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
```

FIGURE C-8. Example printout page from the SHORT Z computer program listing 24-hour average ground-level concentrations from Source 1 calculated at all grid points in the regular array.

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SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                        DATE 03/28/75      PAGE   111

                      *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73              . DATE 032875 *-*-*

                     24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES       1

                                          - HOUR(S)  100 TO    0 -

    X          Y      CONCENTRATION          X          Y      CONCENTRATION          X          Y      CONCENTRATION
             -------------------------------------------------------------------------------------------------------------

 605167.0  4489107.0      .4426691       602976.0  4489036.0      .3751389       579738.0  4482286.0      .0346121
 565143.0  4476619.0      .2281481       585060.0  4476738.0      .2292010       589667.0  4473357.0      .7730466
 596536.0  4472452.0      .5339858       596643.0  4472833.0      .6228511       597786.0  4469464.0     1.2857970
 597976.0  4469702.0     1.0347197       591119.0  4467214.0      .1246708       594869.0  4461869.0      .0000000
 594298.0  4463369.0      .2240199       596284.0  4464238.0     6.2657327       596512.0  4463488.0     9.5180790
 596452.0  4471262.0      .7203346       593726.0  4458357.0      .0000000       597333.0  4456345.0      .0000000
 598202.0  4467262.0     1.1043770       594774.0  4456702.0      .0000000       599012.0  4463560.0      .0001125
 596284.0  4464238.0     6.3771003       596619.0  4462190.0     1.7947592
```
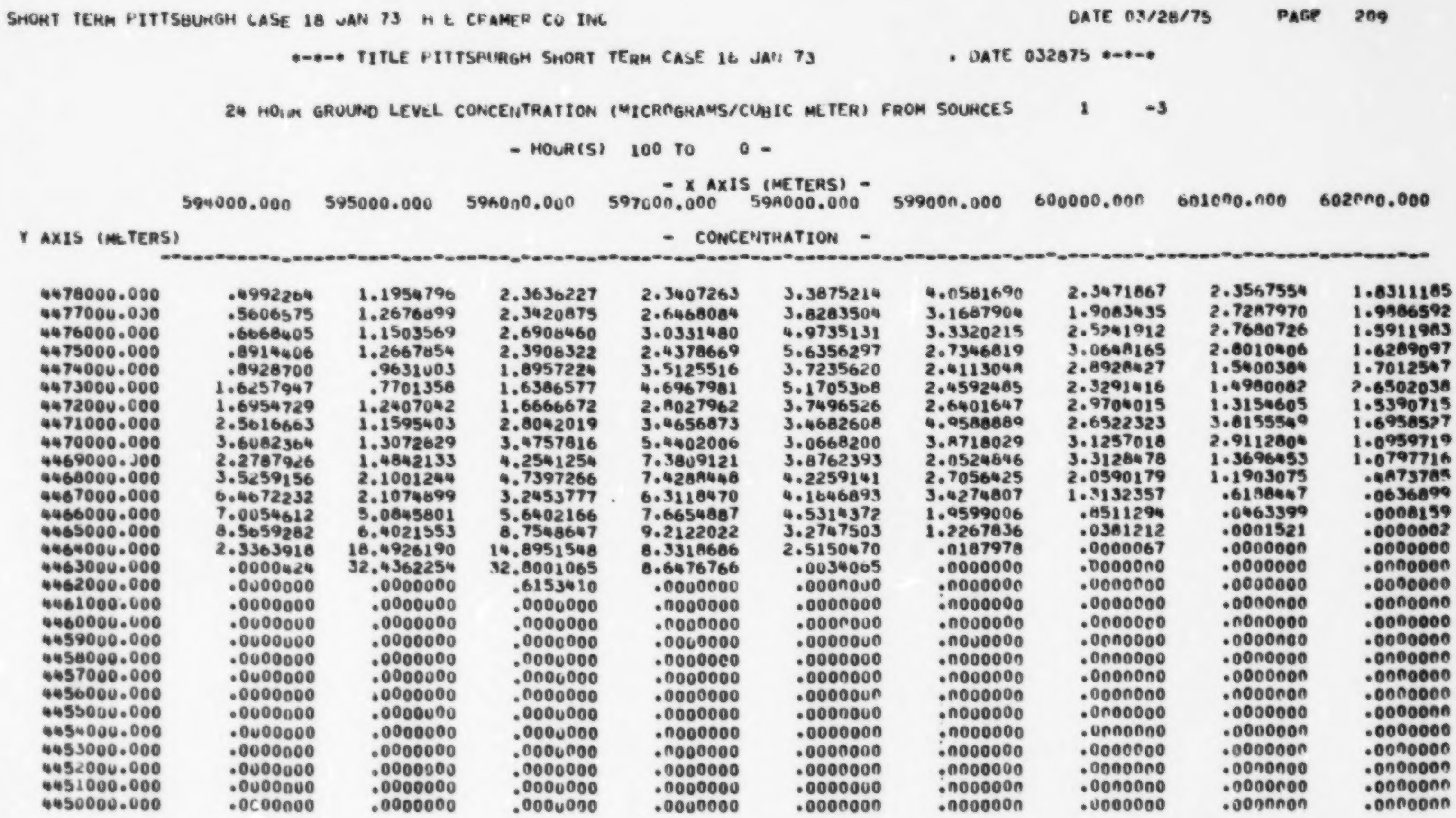

FIGURE C-9. Example printout sheet from the SHORT Z computer program listing 24-hour average ground-level concentrations from Source 1 calculated for all discrete grid-point locations.



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SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                                DATE 03/28/75      PAGE   209

                         *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73              . DATE 032875 *-*-*

                              24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES      1     -3

                                                    - HOUR(S)  100 TO    0 -

                                                                    - X AXIS (METERS) -
                  594000.000      595000.000      596000.000      597000.000      598000.000      599000.000      600000.000      601000.000      602000.000

 Y AXIS (METERS)                                                     -  CONCENTRATION  -
                ---------------------------------------------------------------------------------------------------------------------------------------------

   4478000.000      .4992264       1.1954796       2.3636227       2.3407263       3.3875214       4.0581690       2.3471867       2.3567554       1.8311185
   4477000.000      .5606575       1.2676899       2.3420875       2.6468084       3.8283504       3.1687904       1.9083435       2.7287970       1.9886592
   4476000.000      .6668405       1.1503569       2.6908460       3.0331480       4.9735131       3.3320215       2.5241912       2.7680726       1.5911983
   4475000.000      .8914406       1.2667854       2.3908322       2.4378669       5.6356297       2.7346819       3.0648165       2.8010406       1.6289097
   4474000.000      .8928700        .9631003       1.8957224       3.5125516       3.7235620       2.4113048       2.8928427       1.5400384       1.7012547
   4473000.000     1.6257947        .7701358       1.6386577       4.6967981       5.1705368       2.4592485       2.3291416       1.4980082       2.6502038
   4472000.000     1.6954729       1.2407042       1.6666672       2.8027962       3.7496526       2.6401647       2.9704015       1.3154605       1.5390715
   4471000.000     2.5616663       1.1595403       2.8042019       3.4656873       3.4682608       4.9588889       2.6522323       3.8155549       1.6958527
   4470000.000     3.6082364       1.3072829       3.4757816       5.4402006       3.0668200       3.8718029       3.1257018       2.9112804       1.0959719
   4469000.000     2.2787926       1.4842133       4.2541254       7.3809121       3.8762393       2.0524846       3.3128478       1.3696453       1.0797716
   4468000.000     3.5259156       2.1001244       4.7397266       7.4288448       4.2259141       2.7056425       2.0590179       1.1903075        .4873785
   4467000.000     6.4672232       2.1074899       3.2453777       6.3118470       4.1646893       3.4274807       1.3132357        .6188447        .0636899
   4466000.000     7.0054612       5.0845801       5.6402166       7.6654887       4.5314372       1.9599006        .8511294        .0463399        .0008159
   4465000.000     8.5659282       6.4021553       8.7548647       9.2122022       3.2747503       1.2267836        .0381212        .0001521        .0000002
   4464000.000     2.3363918      18.4926190      14.8951548       8.3318686       2.5150470        .0187978        .0000067        .0000000        .0000000
   4463000.000      .0000424      32.4362254      32.8001065       8.6476766        .0034065        .0000000        .0000000        .0000000        .0000000
   4462000.000      .0000000        .0000000        .6153410        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4461000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4460000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4459000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4458000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4457000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4456000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4455000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4454000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4453000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4452000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4451000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
   4450000.000      .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000        .0000000
```

FIGURE C-10. Example printout sheet from the SHORT Z computer program listing 24-hour average ground-level concentrations from Sources 1 through 3 calculated at each grid point location in the regular array.

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SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                           DATE 03/28/75      PAGE   211

                         *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73            , DATE 032875 *-*-*

                 24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES      1     -3

                                              - HOUR(S)  100 TO    0 -

     X          Y       CONCENTRATION         X          Y       CONCENTRATION        X          Y       CONCENTRATION
            ------------------------------------------------------------------------------------------------------------------

  605167.0  4489107.0     1.3384462       602976.0  4489036.0     1.1177958       579738.0  4482286.0      .1022489
  585143.0  4476619.0      .6772742       585060.0  4476738.0      .6804540       589667.0  4473357.0     2.3270919
  596536.0  4472452.0     1.6948013       596643.0  4472833.0     1.9945661       597786.0  4469464.0     3.7729604
  597976.0  4469702.0     3.1232688       591119.0  4467214.0      .3512151       594869.0  4461869.0      .0000000
  594298.0  4463369.0      .5778215       596284.0  4464238.0    18.8379972       596512.0  4463488.0    24.8704951
  596452.0  4471262.0     2.2957313       593726.0  4458357.0      .0000000       597333.0  4456345.0      .0000000
  598202.0  4467262.0     2.9289127       594774.0  4456702.0      .0000000       599012.0  4463560.0      .0001771
  596284.0  4464238.0    19.1656606       596619.0  4462190.0     2.5372744
```

FIGURE C-11. Example printout sheet from the SHORT Z computer program listing 24-hour average ground-level concentrations from Sources 1 through 3 calculated at all discrete grid points.

of 24-hour average concentrations, produced by emissions from Sources 1 through 3, calculated respectively for regular and discrete grid point locations. Figures C-12 and C-13 show example printout sheets of 24-hour average ground-level concentrations calculated for the combined sources on the regularly-spaced grid and the discrete-point grid, respectively.

C.3 DESCRIPTION OF THE LONG-TERM DIFFUSION-MODEL COMPUTER PROGRAM — LONG Z

C.3.1 Program Capabilities

The computer program entitled LONG Z, which contains the long-term diffusion-models, is written in Fortran IV and is designed to calculate monthly, seasonal and annual average ground-level concentrations of pollutants at a large number of selected grid or receptor points. The program is capable of calculating ground-level concentrations for a maximum of 10,000 individual sources at a maximum of 15,000 grid points. As in the short-term model program, sources are classified in three basic categories (stack, building and area) which can be input in any sequence or combination. The program utilizes a Cartesian coordinate system (usually the Universal Transverse Mercator System UTM) to define the basic calculation grid in which the positive x-axis is directed toward the east (90 degrees) and the positive y axis is directed toward the north (0 or 360 degrees). The grid points may be assigned both on the basis of a regular spacing and at specially selected locations.

This program first calculates, at each grid point, the seasonal and/or annual average ground-level concentration produced by each source; a summing process is used to calculate the ground-level concentrations due to groups of sources and all sources combined after the individual source calculations have been completed. A unique feature of the LONG Z program is the capability of maintaining a master file of the complete source emissions inventory and calculated concentrations on magnetic

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SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                          DATE 03/28/75      PAGE   409

                     *-*-* TITLE PITTSBURGH SHORT TERM CASE 18 JAN 73              , DATE 032875 *-*-*

                  24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES       1     -8

                                              - HOUR(S)  100 TO     0 -

                                                           - X AXIS (METERS) -
                 594000.000   595000.000   596000.000   597000.000   598000.000   599000.000   600000.000   601000.000   602000.000

Y AXIS (METERS)                                                  -  CONCENTRATION  -
                 --------------------------------------------------------------------------------------------------------------

  4478000.000       .8078407    2.0031032    4.1220477    3.8896606    5.6356415    6.8703232    3.9904908    4.0158215    3.1977849
  4477000.000      1.0077578    2.1169761    4.0859546    4.3826804    6.3840225    5.3818803    3.2367089    4.6871955    3.4692145
  4476000.000      1.2080856    1.9142320    4.6961787    5.0065533    8.3190333    5.6751221    4.2748701    4.8014342    2.7550209
  4475000.000      1.6207891    2.1006536    4.1742460    4.0138442    9.4631168    4.6628730    5.2121124    4.8949165    2.7654709
  4474000.000      1.6204513    1.5925936    3.3111602    5.7740709    6.2820629    4.1020142    4.9764049    2.6876405    2.8964833
  4473000.000      2.9267659    1.2724645    2.8632824    7.7182400    8.7724364    4.1643796    4.0647036    2.5552871    4.5950240
  4472000.000      3.0057251    2.0578650    2.9132030    4.6119055    6.3968614    4.4810483    5.2150159    2.2301928    2.7090330
  4471000.000      4.4376140    1.9490204    4.9024825    5.7226426    5.9329726    8.5490563    4.5488686    6.6575519    2.9356931
  4470000.000      6.0833836    2.2613133    6.0758958    9.0403914    5.2159724    6.8202102    5.2813777    5.1397622    1.8330156
  4469000.000      3.8434680    2.6802876    7.4308255   12.3898954    6.5530232    3.5791727    5.8425208    2.3115801    1.8193655
  4468000.000      6.5250692    3.9333241    8.2614031   12.6470083    7.3446408    4.5632191    3.5768658    2.0052626     .8213700
  4467000.000     11.7834208    3.9356332    5.6261947   10.8724905    7.4549552    6.1381330    2.2071619    1.0452825     .1035568
  4466000.000     11.0653225    8.8965589    9.6725087   12.9803202    7.6155684    3.2806807    1.4437743     .0738239     .0012086
  4465000.000     15.8811175   10.8383204   14.6682684   16.5578766    5.7169242    2.1117435     .0581628     .0002085     .0000003
  4464000.000      3.0525156   34.7882004   24.0725684   14.2066821    4.4895267     .0263251     .0000081     .0000000     .0000000
  4463000.000       .0000433   50.2765274   53.7056298   16.6503415     .0038939     .0000000     .0000000     .0000000     .0000000
  4462000.000       .0000000     .0000000    1.0039998     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4461000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4460000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4459000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4458000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4457000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4456000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4455000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4454000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4453000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4452000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4451000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4450000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
```

FIGURE C-12. Example printout sheet from the SHORT Z computer program listing 24-hour average ground-level concentrations from the combined sources (1 through 8) calculated at all grid point locations in the regular array.

```
SHORT TERM PITTSBURGH CASE 18 JAN 73  H E CRAMER CO INC                                        DATE 03/28/75      PAGE   411

                         *-*-* TITLE PITTSBURGH SHORT TERM CASF 18 JAN 73            . DATE 032875 *-*-*

                   24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES      1     -8

                                              - HOUR(S)  100 TO    0 -

     X         Y      CONCENTRATION          X         Y      CONCENTRATION          X         Y      CONCENTRATION
           ----------------------------------------------------------------------------------------------------------------

 605167.0  4489107.0     2.3001241       602976.0  4489036.0     1.8970941       579738.0  4482286.0      .1631359
 585143.0  4476619.0     1.0760478       585060.0  4476738.0     1.0815159       589667.0  4473357.0     4.1095283
 596536.0  4472452.0     2.8193986       596643.0  4472833.0     3.2970305       597786.0  4469464.0     6.4388534
 597976.0  4469702.0     5.3001669       591119.0  4467214.0      .5046496       594869.0  4461869.0      .0000000
 594298.0  4463369.0      .6883526       596284.0  4464238.0    32.3149886       596512.0  4463488.0    47.4937859
 596452.0  4471262.0     3.8107787       593726.0  4458357.0      .0000000       597333.0  4456345.0      .0000000
 598202.0  4467262.0     5.1506255       594774.0  4456702.0      .0000000       599012.0  4463560.0      .0002122
 596284.0  4464238.0    32.8786254       596619.0  4462190.0     2.7379384
```

FIGURE C-13. Example printout sheet from the SHORT Z computer program listing 24-hour average ground-level concentrations from the combined sources (1 through 8) calculated at all discrete grid points.

tape or other convenient computer storage device. This capability allows one to update the information pertaining to a single source or group of sources, to recalculate the updated sources' contribution at each grid point and to resum the contribution from all sources to obtain the updated values of ground-level concentration without redoing all of the original calculations. Considerable savings in computer costs can be realized by using this feature and a current file of the emissions inventory and calculated concentrations is easily maintained and accessed.

The calculations for this study using the LONG Z program were made at the University of Utah Computer Center on a UNIVAC 1108 machine. Operating time for the LONG Z program may be estimated from the expression

$$\text{Operating time in seconds} = RP \times NS \times SE \times VC \times SC \times 0.0008$$

where RP is the number of receptor points, NS is the number of sources, SE is the number of seasons, VC is the number of wind-speed categories and SC is the number of Pasquill stability categories.

C.3.2 Program Input Listings

In addition to the program operating instructions and control statements, the long-term diffusion models requires that the following information be supplied:

- Coordinates and terrain elevations of all grid point locations
- Coordinates and terrain elevations of all sources
- Emission rates for all sources
- Stack data and other source parameters for all sources
- Meteorological parameters

All of the operating, control and input information is listed as part of the computer program output. With the exception of source emission rates and meteorological inputs, these listings are identical in form to those for the short-term model program described in Section C. 2. 2. An example table of source input parameters produced by the LONG Z program is shown in Figure C-14. The table format is the same as that in Figure C-1 for the SHORT Z program, except that the emission rates are in tons per year and are given for each season. If only annual average concentrations are to be calculated, only the emission rate for Season 1 (winter) is used by the program. The entry date column at the extreme left of Figure C-14 shows the date on which the emissions data for each source were last updated.

Figures C-15, C-16 and C-17 are examples of the statistical summaries of meteorological input data provided to the program. Detailed explanations of these tables are presented in Section 3 and Appendix A of this report.

C. 3. 3 Program Output Listings of Ground-Level Concentrations

The output listings of seasonal and annual ground-level concentrations are in the same formats as those shown in Figures C-6 through C-12 for the short-term diffusion-model program, except for the time-frame heading at the top of each printout sheet.

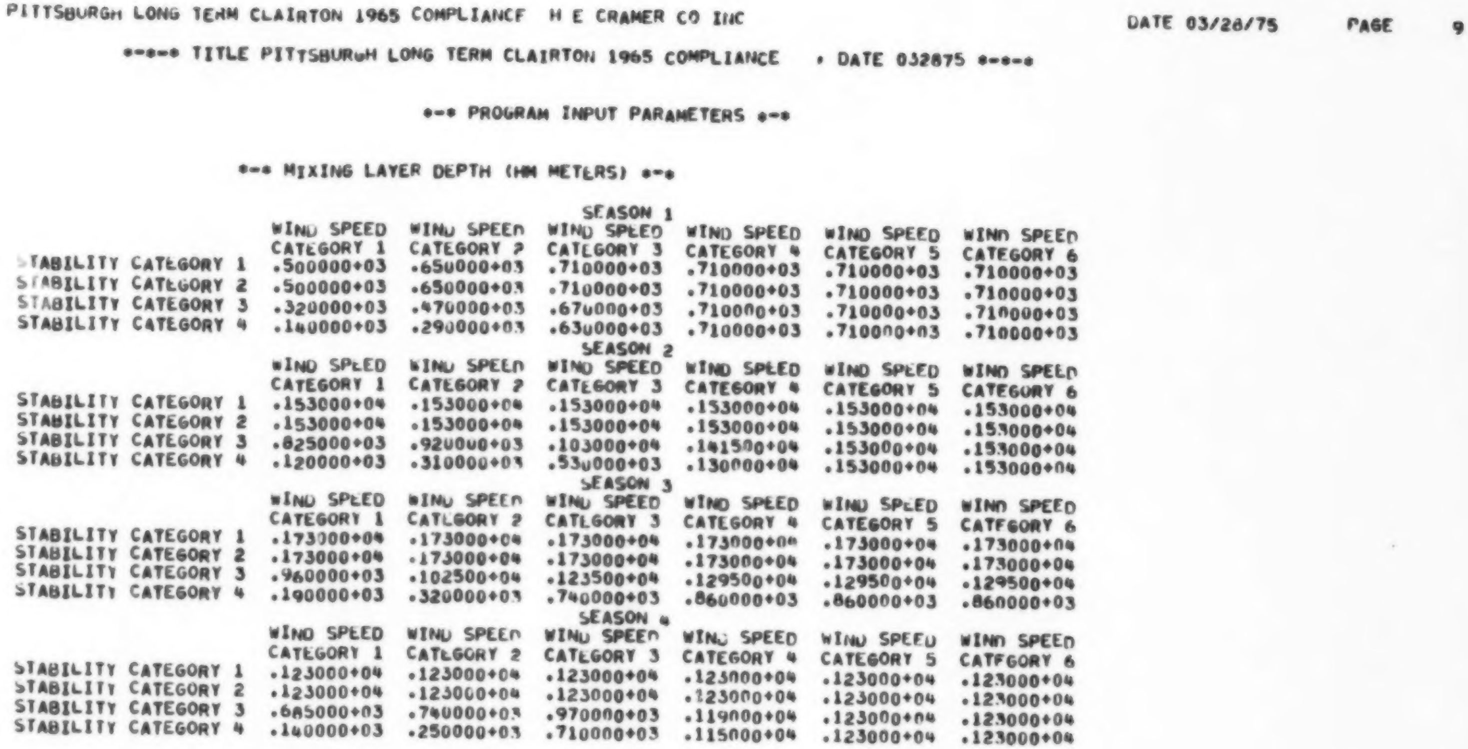
```
PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE  H E CRAMER CO INC                                        DATE 03/28/75      PAGE    22

        *-*-* TITLE PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE   , DATE 032875 *-*-*

                                                       *-* OUTPUT TAPE SOURCE INVENTORY LISTING *-*

ENTRY SOURCE T      SOURCE STRENGTH (TONS/YEAR)              X          Y        HEIGHT ELEVATION  IF TYPE=0     IF TYPE=0      STACK
 DATE NUMBER Y                                                                   ABOVE      AT     TEMP (DEG K)  VOL. EMISS.   INTERNAL
MODYYR       P SEASON 1  SEASON 2  SEASON 3  SEASON 4 COORDINATE COORDINATE  GROUND    BASE     IF TYPE=1OR2 RT, M**3/SEC   RADIUS
             E OR ANNUAL                               (METERS)   (METERS)  (METERS) (METERS)  LENGTH SHORT   IF TYPE=1OR2  (MTR)
                                                                                               SIDE (METERS) LENGTH LONG
                                                                                                             SIDE (MTRS)
021675     1 0   120.000   120.000   120.000   120.000 595860.00 4461520.00   69.00    229.00        700.000        37.270     1.22
021675     2 0   120.000   120.000   120.000   120.000 595830.00 4461540.00   69.00    229.00        700.000        37.270     1.22
021675     3 0   120.000   120.000   120.000   120.000 595730.00 4461780.00   69.00    229.00        700.000        37.270     1.22
021675     7 0   120.000   120.000   120.000   120.000 595880.00 4461650.00   65.00    229.00        700.000        35.870     1.27
021675     8 0   120.000   120.000   120.000   120.000 595870.00 4461680.00   65.00    229.00        700.000        35.870     1.27
021675     9 0   120.000   120.000   120.000   120.000 595750.00 4461810.00   65.00    229.00        700.000        35.870     1.27
021675    10 0   120.000   120.000   120.000   120.000 595660.00 4461900.00   69.00    229.00        700.000        37.270     1.22
021675    11 0   120.000   120.000   120.000   120.000 595630.00 4461920.00   69.00    229.00        700.000        37.270     1.22
021675    12 0   120.000   120.000   120.000   120.000 595520.00 4462060.00   69.00    229.00        700.000        37.270     1.22
021675    13 0   120.000   120.000   120.000   120.000 595380.00 4461930.00   69.00    229.00        700.000        37.740     1.31
021675    14 0   120.000   120.000   120.000   120.000 595360.00 4461960.00   69.00    229.00        700.000        37.740     1.31
021675    15 0   120.000   120.000   120.000   120.000 595210.00 4462110.00   69.00    229.00        700.000        37.740     1.31
021675    16 0   120.000   120.000   120.000   120.000 595190.00 4462150.00   61.00    229.00        700.000        32.130     1.31
021675    17 0   120.000   120.000   120.000   120.000 595110.00 4462240.00   61.00    229.00        700.000        32.130     1.31
021675    18 0   120.000   120.000   120.000   120.000 595020.00 4462330.00   76.00    229.00        700.000        32.300     1.46
021675    19 0   120.000   120.000   120.000   120.000 595280.00 4461880.00   76.00    229.00        700.000        58.430     2.14
021675    20 0   120.000   120.000   120.000   120.000 595250.00 4461910.00   76.00    229.00        700.000        58.430     2.14
021675    21 0   120.000   120.000   120.000   120.000 595060.00 4462120.00   76.00    229.00        700.000        58.430     2.14
021675    22 0   120.000   120.000   120.000   120.000 595030.00 4462160.00   76.00    229.00        700.000        58.430     2.14
021675    23 0   120.000   120.000   120.000   120.000 595500.00 4462080.00   69.00    229.00        700.000        35.870     1.52
021675    24 0  2062.000  2062.000  2062.000  2062.000 595000.00 4462470.00   50.00    229.00        455.000        92.570     1.37
021675    25 0  1537.000  1537.000  1537.000  1537.000 595000.00 4462470.00   50.00    229.00        455.000        72.330     1.06
021675    26 1   723.000   723.000   723.000   723.000 594870.00 4462400.00   52.00    229.00         16.000        60.000      .00
021675    27 1   723.000   723.000   723.000   723.000 594850.00 4462410.00   52.00    229.00         16.000        60.000      .00
021675    28 0   299.000   299.000   299.000   299.000 595630.00 4460060.00   60.00    229.00        716.000       180.580     1.88
021675    30 0  1413.000  1413.000  1413.000  1413.000 595810.00 4461550.00   46.00    229.00        561.000        18.030      .61
021675    31 0   683.000   683.000   683.000   683.000 593220.00 4465600.00   55.00    282.00        646.000        54.950     1.79
021675    32 0   971.000   971.000   971.000   971.000 593230.00 4465650.00   78.00    282.00        633.000        79.620     1.60
021675    33 0   756.000   756.000   756.000   756.000 593250.00 4465710.00   30.00    282.00        483.000        33.400      .92
021675    38 0 12994.000 12994.000 12994.000 12994.000 592000.00 4456200.00   89.00    229.00        416.000       299.140     2.30
021675    39 0  6690.000  6690.000  6690.000  6690.000 587340.00 4452810.00   73.00    229.00        403.000       534.810     3.05
021675    40 0  1945.000  1945.000  1945.000  1945.000 587340.00 4452810.00   70.00    229.00        467.000       223.640     2.15
021675    41 0  1945.000  1945.000  1945.000  1945.000 587340.00 4452810.00   70.00    229.00        467.000       223.640     2.15
021675    42 0  1945.000  1945.000  1945.000  1945.000 587340.00 4452810.00   70.00    229.00        467.000       223.640     2.15
021675    43 1   150.000   150.000   150.000   150.000 593250.00 4465700.00   52.00    282.00         10.000        50.000      .00
021675    44 1   150.000   150.000   150.000   150.000 593250.00 4465600.00   52.00    282.00         10.000        50.000      .00
021675    45 1   150.000   150.000   150.000   150.000 593250.00 4465650.00   52.00    282.00         10.000        50.000      .00
021675    46 1   150.000   150.000   150.000   150.000 593260.00 4465600.00   52.00    282.00         10.000        50.000      .00
021675    47 1   150.000   150.000   150.000   150.000 593260.00 4465650.00   52.00    282.00         10.000        50.000      .00
021675    48 1    48.000    48.000    48.000    48.000 595100.00 4461520.00   52.00    229.00         70.000        70.000      .00
021675    49 1    48.000    48.000    48.000    48.000 595100.00 4461530.00   52.00    229.00         70.000        70.000      .00
021675    50 1    48.000    48.000    48.000    48.000 595100.00 4461540.00   52.00    229.00         70.000        70.000      .00
021675    51 1    48.000    48.000    48.000    46.000 595100.00 4461550.00   52.00    229.00         70.000        70.000      .00
021675    52 1    48.000    48.000    48.000    46.000 595100.00 4461560.00   52.00    229.00         70.000        70.000      .00
```

FIGURE C-14. Example printout page from the LONG Z computer program listing source input data.



```
PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE  H E CRAMER CO INC                               DATE 03/28/75     PAGE    9
       *-*-* TITLE PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE   , DATE 032875 *-*-*

                                  *-* PROGRAM INPUT PARAMETERS *-*

                    *-* MIXING LAYER DEPTH (HM METERS) *-*

                                                  SEASON 1
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .500000+03   .650000+03   .710000+03   .710000+03   .710000+03   .710000+03
STABILITY CATEGORY 2      .500000+03   .650000+03   .710000+03   .710000+03   .710000+03   .710000+03
STABILITY CATEGORY 3      .320000+03   .470000+03   .670000+03   .710000+03   .710000+03   .710000+03
STABILITY CATEGORY 4      .140000+03   .290000+03   .630000+03   .710000+03   .710000+03   .710000+03
                                                  SEASON 2
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .153000+04   .153000+04   .153000+04   .153000+04   .153000+04   .153000+04
STABILITY CATEGORY 2      .153000+04   .153000+04   .153000+04   .153000+04   .153000+04   .153000+04
STABILITY CATEGORY 3      .825000+03   .920000+03   .103000+04   .141500+04   .153000+04   .153000+04
STABILITY CATEGORY 4      .120000+03   .310000+03   .530000+03   .130000+04   .153000+04   .153000+04
                                                  SEASON 3
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .173000+04   .173000+04   .173000+04   .173000+04   .173000+04   .173000+04
STABILITY CATEGORY 2      .173000+04   .173000+04   .173000+04   .173000+04   .173000+04   .173000+04
STABILITY CATEGORY 3      .960000+03   .102500+04   .123500+04   .129500+04   .129500+04   .129500+04
STABILITY CATEGORY 4      .190000+03   .320000+03   .740000+03   .860000+03   .860000+03   .860000+03
                                                  SEASON 4
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .123000+04   .123000+04   .123000+04   .123000+04   .123000+04   .123000+04
STABILITY CATEGORY 2      .123000+04   .123000+04   .123000+04   .123000+04   .123000+04   .123000+04
STABILITY CATEGORY 3      .685000+03   .740000+03   .970000+03   .119000+04   .123000+04   .123000+04
STABILITY CATEGORY 4      .140000+03   .250000+03   .710000+03   .115000+04   .123000+04   .123000+04
```

FIGURE C-15. Example printout page from the LONG Z computer program listing mixing layer depths by season for each stability category and wind speed category.

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PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE  H E CRAMER CO INC                                  DATE 03/28/75      PAGE    17

             *-*-* TITLE PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE    , DATE 032875 *-*-*

                                       *-* PROGRAM INPUT PARAMETERS *-*

                        *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*

                                                   SEASON 4

                                              STABILITY CATEGORY 3

                   WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                   CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION      (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
      .000          .00038040   .00274730   .01785710   .00824180   .00000000   .00000000
    22.500          .00076080   .00549450   .00412090   .00137360   .00000000   .00000000
    45.000          .00019020   .00137360   .00274730   .00000000   .00000000   .00000000
    67.500          .00057060   .00412090   .00686810   .00137360   .00000000   .00000000
    90.000          .00076060   .00549450   .00824180   .00137360   .00000000   .00000000
   112.500          .00095100   .00686810   .01236260   .00412090   .00000000   .00000000
   135.000          .00076080   .00549450   .01098900   .00824180   .00000000   .00000000
   157.500          .00038040   .00274730   .00274730   .00824180   .00000000   .00000000
   180.000          .00114120   .00824180   .01510990   .01236260   .00000000   .00000000
   202.500          .00038040   .00274730   .00824180   .02197800   .00000000   .00000000
   225.000          .00289520   .00961540   .03296701   .05906591   .00549450   .00000000
   247.500          .00251480   .00686810   .02335160   .03021981   .00686810   .00824180
   270.000          .00076080   .00549450   .04120881   .04258241   .00961540   .00000000
   292.500          .00057060   .00412090   .01098900   .01785710   .00686810   .00274730
   315.000          .00445900   .00961540   .00961540   .01236260   .00137360   .00137360
   337.500          .00038040   .00274730   .00549450   .00686810   .00000000   .00000000

                                                   SEASON 4

                                              STABILITY CATEGORY 4

                   WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                   CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION      (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
      .000          .00582660   .00824180   .00274730   .00000000   .00000000   .00000000
    22.500          .00623420   .01510990   .00274730   .00000000   .00000000   .00000000
    45.000          .00582660   .00824180   .00137360   .00000000   .00000000   .00000000
    67.500          .00356240   .01236260   .00137360   .00000000   .00000000   .00000000
    90.000          .01933640   .02060440   .00000000   .00000000   .00000000   .00000000
   112.500          .00671720   .00961540   .00000000   .00000000   .00000000   .00000000
   135.000          .00946440   .01236270   .00274730   .00000000   .00000000   .00000000
   157.500          .01124560   .00824170   .00137360   .00000000   .00000000   .00000000
   180.000          .01254360   .01785710   .00137360   .00000000   .00000000   .00000000
   202.500          .00267160   .00549450   .00686810   .00000000   .00000000   .00000000
   225.000          .00582660   .00686810   .00686810   .00000000   .00000000   .00000000
   247.500          .00582660   .00686810   .00274730   .00000000   .00000000   .00000000
   270.000          .00898140   .01648350   .00549450   .00000000   .00000000   .00000000
   292.500          .00630960   .00412090   .00549450   .00000000   .00000000   .00000000
   315.000          .00089060   .00274720   .00412090   .00000000   .00000000   .00000000
   337.500          .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
```

FIGURE C-16. Example printout sheet from the LONG Z computer program listing joint occurrence frequencies of wind speed and direction categories.

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PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE  H E CRAMER CO INC                              DATE 03/28/75      PAGE    18

        *-*-* TITLE PITTSBURGH LONG TERM CLAIRTON 1965 COMPLIANCE    , DATE 032875 *-*-*

                                          *-* PROGRAM INPUT PARAMETERS *-*

     *-* STANDARD DEVIATION OF THE WIND ELEVATION ANGLE FOR ELEVATED POINT OR VOLUME SOURCES (SIGEPU RADIANS) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
 STABILITY CATEGORY 1     .174500+00   .174500+00   .174500+00   .174500+00   .174500+00   .174500+00
 STABILITY CATEGORY 2     .108000+00   .108000+00   .108000+00   .108000+00   .108000+00   .108000+00
 STABILITY CATEGORY 3     .735000-01   .735000-01   .735000-01   .735000-01   .735000-01   .735000-01
 STABILITY CATEGORY 4     .465000-01   .465000-01   .465000-01   .465000-01   .465000-01   .465000-01

     *-* STANDARD DEVIATION OF THE WIND ELEVATION ANGLE FOR AREA OR BUILDING EMISSIONS SOURCES (SIGEPL RADIANS) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
 STABILITY CATEGORY 1     .174500+00   .174500+00   .174500+00   .174500+00   .174500+00   .174500+00
 STABILITY CATEGORY 2     .108000+00   .108000+00   .108000+00   .108000+00   .108000+00   .108000+00
 STABILITY CATEGORY 3     .735000-01   .735000-01   .735000-01   .735000-01   .735000-01   .735000-01
 STABILITY CATEGORY 4     .465000-01   .465000-01   .465000-01   .465000-01   .465000-01   .465000-01

                          *-* VERTICAL POTENTIAL TEMPERATURE GRADIENT (DPDZ DEGREES KELVIN) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
 STABILITY CATEGORY 1     .000000      .000000      .000000      .000000      .000000      .000000
 STABILITY CATEGORY 2     .000000      .000000      .000000      .000000      .000000      .000000
 STABILITY CATEGORY 3     .150000-01   .100000-01   .500000-02   .300000-02   .300000-02   .300000-02
 STABILITY CATEGORY 4     .300000-01   .200000-01   .150000-01   .300000-02   .300000-02   .300000-02

                          *-* WIND PROFILE POWER LAW EXPONENT (P) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
 STABILITY CATEGORY 1     .100000+00   .100000+00   .100000+00   .100000+00   .100000+00   .100000+00
 STABILITY CATEGORY 2     .200000+00   .150000+00   .100000+00   .100000+00   .100000+00   .100000+00
 STABILITY CATEGORY 3     .250000+00   .200000+00   .150000+00   .100000+00   .100000+00   .100000+00
 STABILITY CATEGORY 4     .300000+00   .250000+00   .200000+00   .200000+00   .200000+00   .200000+00
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FIGURE C-17. Example printout sheet from the LONG Z computer program listing various meteorological input parameters.